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Journal

of

THE ROYAL AERONAUTICAL SOCIETY

DECEMBER 1957

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All communications for publication in, and advertisements for, the JOURNAL *should be addressed to the Editor,* JOAN BRADBROOKE, *A.R.Ae.S.; all communications on general matters affecting the Society should be addressed to the Secretary,* A. M. BALLANTYNE, *T.D., B.Sc., Ph.D., Hon.F.C.A.I., A.F.I.A.S., F.R.Ae.S.*

None of the papers or paragraphs must be taken as expressing the opinion of the Council of the Royal Aeronautical Society unless otherwise stated.

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NOTICES

The President, Sir George Edwards, the Council and the Staff of the Society wish all members at home and overseas a happy Christmas.

Christmas 1957

The Library and Offices of the Society will be closed for the Christmas Holiday from 5.0 p.m. on Tuesday 24th December until 9.0 a.m. on Monday 30th December 1957.

Associate Fellowship Examinations, December 1957

The Associate Fellowship Examinations will be held on the 17th, 18th, 19th and 20th December 1957 in the United Kingdom and at various Centres abroad. All Candidates will be sent a time-table and full instructions.

Royal Aeronautical Society Prizes in Aeronautics

The Royal Aeronautical Society Prizes in Aeronautics for 1957 have been awarded as follows:—

University of Bristol	D. N. Foster
Cambridge University	P. Bradshaw
Imperial College of Science and Technology	Suresh Bhagat
Queen Mary College	J. T. Everest
College of Aeronautics	Lt. Hartland A. Gray
Glasgow University	David A. Pirie
University of Southampton	Tudor Sprinks
Northampton College of Technology	B. J. Edwards

Acknowledgments

The Council wish to thank Sir Thomas Sopwith, C.B.E., *Hon. Fellow*, and Sir Frank Spencer Spriggs, K.B.E., *Hon. Fellow*, for presenting to the Library photographs of the first deck landing trials and of early Sopwith types of aircraft.

They also thank Mr. J. A. Williams, of Laporte Chemicals Ltd., for presenting a copy of "Pilgrims and Pioneers" by Sir Harry Brittain, and Mr. J. H. Woodward, of Bearsden, Dunbartonshire, for presenting a number of books.

Engineering and Metallurgical Aspects of Fatigue

A Course of 10 lectures on "Engineering and Metallurgical Aspects of Fatigue" is to be held by the Metallurgy Department of the Battersea College of Technology from the 14th January until the 18th March 1958. The lectures, which will be given on Tuesday evenings from 7.00 to 9.00 p.m. will be:—

1. The Nature of Fatigue, A. P. Miodownik (Battersea College of Technology). 2. The Influence of Combined Stresses, S. R. House (Battersea College of Technology). 3. The Influence of Corrosion, P. T. Gilbert (Yorkshire Copper Works Ltd.). 4. The Influence of Temperature, P. G. Forrest (N.P.L.). 5. The Influence of Design, Lecturer to be announced. 6. The Metallography of Fatigue, P. J. E. Forsythe (R.A.E.). 7. The Mechanism of Fatigue, T. Broom (University of Birmingham). 8. Fatigue Testing, M. G. Bader (Battersea College of Technology). 9. The Interpretation of Fatigue Data, H. L. Cox (N.P.L.). 10. The Fatigue Properties of Engineering Materials, R. J. Love (Motor Industries Research Association).

The fee for the Course will be £1 0s. 0d. Enrolment forms may be obtained from the Secretary (Fatigue Lectures), Battersea College of Technology, Battersea Park Road, London, S.W.11.

Presidential Address
Wednesday 26th February 1958

Sir George R. Edwards will deliver his Presidential Address on Wednesday 26th February 1958 at Church House, Westminster, London, S.W.1, at 6.0 p.m. The address will be followed by a Reception at 4 Hamilton Place, London, W.1, and full particulars of the arrangements and the Reception will be sent to all members.

Library

It is regretted that the Library will be closed during the four days of the Associate Fellowship Examination, 17th, 18th, 19th and 20th December.

Sir George Cayley Lecture

A lecture on "Sir George Cayley (1773-1857): A Pioneer of Science and Engineering" is being given by Captain J. L. Pritchard, C.B.E., Hon.F.I.A.S., Hon. F.R.Ae.S., at the Royal Society of Arts, John Adam Street, Adelphi, on Wednesday 18th December at 2.30 p.m. Mr. C. H. Gibbs-Smith, *Companion*, will be in the Chair. Visitors' Tickets may be obtained on application to the Secretary, Royal Society of Arts.

Third European Aeronautical Conference

The Third European Aeronautical Conference, organised under the auspices of the International Association of Aeronautical Equipment Manufacturers (A.I.C.M.A.) by the Belgian Group of Aeronautical Equipment Manufacturers (GEBECOMA) is to be held in connection with the Universal and International Exhibition being held in Brussels in 1958. The Conference will take place from the 22nd-27th September 1958 in Brussels.

Sections to be covered by the Conference include 1. Performance; 2. Design Methods and New Procedures in Aircraft Construction; 3. Progress and Trends in Aviation Electronics. The official languages are French, English and German and those wishing to present papers are asked to communicate with the General Secretariat of the Organising Committee as quickly as possible. The final date for the acceptance of papers is **15th January 1958.**

Full particulars of the Conference may be obtained from: The General Secretary, Organising Committee, Third European Aeronautical Conference, 1470 Chaussée de Haecht, Haren, Belgium.

Annual Subscriptions

Members are reminded that their annual subscriptions become due on 1st January 1958. The rates are:—

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	£	s.	d.	£	s.	d.
Fellows	5	5	0	4	4	0
Associate Fellows	4	4	0	3	3	0
*Associates	3	3	0	3	3	0
Graduates (aged under 26)	2	2	0	2	2	0
Graduates (aged 26 and over)	2	12	6	2	12	6
Students (aged under 21)	1	1	0	1	1	0
Students (aged 21 and over)	1	11	6	1	11	6
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* Any Associate elected before 1st October 1947 may, if he wishes, elect not to receive the Journal, and in this case his subscription will be reduced by £1 1s. 0d. to £2 2s. 0d.

It will avoid delay and confusion if members, when sending remittances for subscriptions, will state their names clearly and give their addresses and grades of membership. Remittances should be made payable to the Royal Aeronautical Society.

DIARY

LONDON

12th December

MAIN LECTURE.—Ram Jets. R. P. Probert. Institution of Mechanical Engineers, Birdcage Walk, S.W.1. 6 p.m. (Tea at 5.30 p.m.)

17th December

SECTION LECTURE.—Comparison of Ducted Fan, By-pass and Straight Jet Engines. Dr. S. G. Hooker. Library, 4 Hamilton Place, W.1. 7 p.m.

2nd January 1958

YOUNG PEOPLE'S LECTURE.—Some Aspects of Test Flying. A. W. Bedford. Royal Society of Arts, 6 John Adam Street, W.C.2. 3 p.m.

15th January

MAIN LECTURE AT LEICESTER BRANCH.—Rolls-Royce Engines. A. A. Lombard. Lecture Theatre, Loughborough College. 6.45 p.m.

21st January

SECTION LECTURE.—Environments and Environmental Testing. P. J. Duncton. Library, 4 Hamilton Place W.1. 7 p.m.

4th February

SECTION LECTURE.—Power Controls for Supersonic Aircraft. G. Selwood. Library, 4 Hamilton Place, W.1. 7 p.m.

13th February

MAIN LECTURE.—The Application of the Theory of Stability in Structural Design. H. L. Cox. Institution of Mechanical Engineers, Birdcage Walk, S.W.1. 6 p.m. (Tea 5.30 p.m.)

20th February

MAIN LECTURE AT HALTON BRANCH. THE FIRST TRENCHARD MEMORIAL LECTURE.—Air Chief Marshal Sir Dermot Boyle. Branch Hut, R.A.F. Halton. 6.45 p.m.

GUIDED FLIGHT SECTION

23rd January 1958

GUIDANCE AND CONTROL. L. H. Bedford. Library, 4 Hamilton Place, W.1. 7 p.m.

25th February

GUIDED FLIGHT TRIALS. R. W. Boswell. Library, 4 Hamilton Place, W.1. 7 p.m.

GRADUATES' AND STUDENTS' SECTION

10th December

Film Show. Library, 4 Hamilton Place, W.1. 7.30 p.m.

11th January 1958

Visit to Vickers-Armstrongs (Aircraft) Ltd., Weybridge.

1st February

Visit to Guinness Brewery, Park Royal, Middlesex.

BRANCHES

9th December

Halton.—Flight Test Development of the Gnat. E. A. Tennant. Branch Hut, R.A.F. Halton. 6.45 p.m.

10th December

Bristol.—Aviation Finance. G. E. Knight. Filton House. 6 p.m.

London Airport.—Airline Economics. Stephen Wheatcroft. B.E.A. Viking Centre Cinema, Hatton Cross, 6 p.m.

11th December

Brough.—Future Trends of Aircraft Propulsion Units. Air Cdre. F. R. Banks. Royal Station Hotel, Hull. 7.30 p.m.

Chester.—Lecturettes. Lecture Theatre, Grosvenor Museum, Chester. 7.30 p.m.

Christchurch.—Fatigue Tests on the Bristol "Britannia." Dr. W. J. Strang. King's Arms Hotel. 7.30 p.m.

Hatfield.—The Domain of the Helicopter. R. Hafner. de Havilland Restaurant, Hatfield. 6.15 p.m.

Reading.—The Investigation of Aircraft Accidents. E. L. Ripley. Upper Canteen, Western Manufacturing (Reading) Ltd. 6 p.m.

Weybridge.—The International Geophysical Year. H. S. W. Massey. Apprentice Training School, Vickers-Armstrongs (Aircraft) Ltd. 6 p.m.

12th December

Cheltenham.—Problems of Progressive Failure. Sir Alfred Pugsley. St. Mary's College, Cheltenham. 7.30 p.m.

Glasgow.—Fatigue and Fail-Safe in Aircraft Structures. N. F. Harpur. Room 24, College of Science and Technology, Duke Street, Glasgow. 7.15 p.m.

Isle of Wight.—Annual General Meeting and Film Show. Clubhouse, Saunders-Roe Sports and Social Club, E. Cowes. 6.30 p.m.

Southampton.—The Weapons System Concept. Handel Davies. Institute of Education Lecture Theatre, University of Southampton. 8 p.m. **Note change of date, time and place.**

16th December

Henlow.—Artificial Satellites. Dr. M. W. Ovenden. Building 62, R.A.F. Technical College, Henlow. 7.30 p.m.

17th December

Boscombe Down.—The Weapons System Concept. Handel Davies. Lecture Hall A. and A.E.E. 5.45 p.m. **Postponed from 3rd December.**

20th December

Weybridge.—Annual Dance.

6th January 1958

Derby.—Missile Guidance. E. V. Truefitt. Rolls-Royce Welfare Hall, Nightingale Road, Derby. 6.45 p.m.

Halton.—Film Night. Branch Hut, R.A.F. Halton. 6.45 p.m.

7th January

London Airport.—Airline Operational Flying. Capt. W. Baille; and Film—"London Airport." 6 p.m. B.E.A. Viking Centre Cinema. 6 p.m.

Luton.— Junior Paper Evening. Napier Senior Staff Canteen, Luton Airport. 6.15 p.m.

8th January

Bristol.—Fail-Safe Structures. N. F. Harpur. Filton House. 6 p.m.

Brough.—Young People's Christmas Lecture. The Speed Record. L. P. Twiss. Newland High School, Cottingham Road, Hull. (Afternoon.)

Gloucester.—The Design and Development of the Aeronautical Gas Turbine with Special Reference to the Rolls-Royce Dart. L. Howarth. The Wheatstone Hall, Brunswick Road, Gloucester. 7.30 p.m.

Hatfield.—Social Evening. de Havilland Restaurant, Hatfield.

Reading.—Automatic Pilots. N. Sullivan and F. A. Summerlin. Upper Canteen, Western Manufacturing (Reading) Ltd. 6 p.m.

Southampton.—Annual General Meeting and Film Show. Institute of Education, University of Southampton. 7 p.m.

Weybridge.—Brain's Trust. Apprentice Training School, Vickers-Armstrongs (Aircraft) Ltd. 6 p.m.

9th January.

Isle of Wight.—Modern Tank Testing. W. A. Crago. Clubhouse, Saunders-Roe Sports and Social Club, E. Cowes. 6.30 p.m.

13th January

Glasgow.—Guided Weapons. J. J. Gait. Room 24, College of Science and Technology, Duke Street, Glasgow. 7.15 p.m.

Halton.—Impressions of Soviet Aviation. C. Jenkins. Branch Hut, R.A.F. Halton. 6.45 p.m.

Henlow.—Procedures of Test Flying at Supersonic Speeds. Wg. Cdr. R. P. Beamont. Building 62, R.A.F. Technical College, Henlow. 7.30 p.m.

14th January

Boscombe Down.—Aircraft Control. Prof. G. A. Whitfield. Lecture Hall, A. and A.E.E. 5.45 p.m.

Cambridge.—Medical Aspects of Modern Aviation. Wg. Cdr. Lewis. No. 1 Lecture Theatre, Cambridge University Engineering Laboratories. 8.15 p.m.

15th January

Brough.—Aviation's Prophets. Capt. J. L. Pritchard. Lecture Hall, Electricity Offices, Ferensway, Hull. 7.30 p.m.

Chester.—Nuclear Propulsion of Aircraft. R. E. Wigg. Lecture Theatre, Grosvenor Museum, Chester. 7.30 p.m.

Leicester.—Main Society Lecture. Rolls-Royce Engines. A. A. Lombard. Lecture Theatre, Loughborough College. 6.45 p.m.

16th January

Christchurch.—The International Geophysical Year. Dr. R. d'E. Atkinson. Town Hall, Christchurch. 7.30 p.m.

18th January
Birmingham.—Airworthiness for the A.R.B. W. Tye. Engineering Centre, Birmingham. 7.30 p.m.

20th January
Halton.—Film Night. Branch Hut, R.A.F. Halton. 6.45 p.m.

21st January
Luton.—New Methods of Approach to Airworthiness. W. Tye. Napier Senior Staff Canteen, Luton Airport. 6.15 p.m.

22nd January
Hatfield.—Submarine Design Problems. E. A. Brokensha. de Havilland Restaurant, Hatfield. 6.15 p.m.

23rd January
Isle of Wight.—A Bush Pilot in the Far North. R. J. P. Barber. Clubhouse, Saunders-Roe Sports and Social Club, E. Cowes. 6.30 p.m.

27th January
Halton.—Film Night. Branch Hut, R.A.F. Halton. 6.45 p.m.

28th January
Bristol.—Aircraft Flight Systems. Capt. A. M. A. Majendie. Filton House. 6 p.m.

29th January
Southampton.—Flight Testing Procedures at Supersonic Speeds. Wg. Cdr. R. P. Beamont. Institute of Education, University of Southampton. 7 p.m.
Weybridge.—Film Show. Apprentice Training School, Vickers-Armstrongs (Aircraft) Ltd. 6 p.m.

31st January
Chester.—Annual Dance. Quaintways Restaurant, Chester. 8 p.m.-1 a.m.

3rd February
Derby.—Annual General Meeting. Ten-minute Papers. Rolls-Royce Welfare Hall, Nightingale Road, Derby. 6.15 p.m.
Henlow.—Annual General Meeting. Building 62, R.A.F. Technical College, Henlow. 7.30 p.m.

4th February
Glasgow.—Pilcher Memorial Lecture. History of Scottish Aviation. D. F. McIntyre. Room 24, College of Science and Technology, Duke Street, Glasgow. 7.15 p.m.
Luton.—Development of the Armstrong Siddeley Viper. W. H. Lindsey. Napier Senior Staff Canteen, Luton Airport. 6.15 p.m.

5th February
Brough.—Supersonic Aircraft and Missiles. P. J. Duncton. Lecture Hall, Electricity Offices, Ferensway, Hull. 7.30 p.m.
London Airport.—Noise. Professor E. J. Richards. Apprentice Lecture Room, Fairey Aviation Co. Ltd., Hayes. 6 p.m.
Reading—Ultra Sonic Testing. J. Crowther. Upper Canteen, Western Manufacturing (Reading) Ltd. 6 p.m.

6th February
Bristol.—Design of Civil Aircraft. D. P. Thorne. Filton House. 6 p.m.
Isle of Wight.—The Development of the Rotodyne and Gyrodyne. D. M. Davies. Clubhouse, Saunders-Roe Sports and Social Club, E. Cowes. 6.30 p.m.
Swindon.—Joint Lectures with Swindon Engineering Society. Gas Turbines as applied to Rail Traction. R. J. Harding, **and** Aircraft Gas Turbines. A. C. Lovesey. The College, Victoria Road, Swindon. 7 p.m.

11th February
Boscombe Down.—Film Evening. Lecture Hall, A. and A.E.E. 5.45 p.m.

12th February
Chester.—Joint Meeting with Stanlow Branch of Institute of Petroleum. Aircraft Fuelling Problems. E. L. Bass. Lecture Theatre, Grosvenor Museum, Chester. 7.30 p.m.

13th February
Cheltenham.—The Microscope in Engineering. A. E. Bingham. St. Mary's College, Cheltenham. 7.30 p.m.
Bristol.—Production of Civil Aircraft. By a member of Vickers-Armstrongs (Aircraft) Ltd. Filton House. 6 p.m.

News of Members

R. C. Aikman (*Graduate*), formerly a Pilot Officer in the Technical Engineering Branch of the R.A.F., is now employed as an Installation Engineer for the Graviner Manufacturing Company, Colnbrook.

G. W. Aspin (*Associate*), formerly with the Civil Aviation Administration, is now with the Aviation Division of Brown and Dureau (New Zealand) Ltd.

J. L. Buckworth (*Student*) is now a Weights Estimator with Avro Aircraft Ltd., Toronto, Canada.

N. N. Budish (*Associate Fellow*), formerly Visiting Lecturer with the rank of Associate Professor, Princeton University, New Jersey, is now a Preliminary Design Engineer with Boeing Airplane Company, Renton, Washington.

A. W. Burns (*Associate*), formerly Senior Design Draughtsman with Vickers-Armstrongs (Aircraft) Ltd., Supermarine Works, is now Aircraft Designer at Avro Aircraft Ltd., Malton, Ontario.

A. D. S. Carter (*Associate Fellow*), formerly with the Ministry of Supply at the National Gas Turbine Establishment, has been appointed Professor of Mechanical Engineering at the Royal Military College of Science, Shrivenham, Swindon.

A. M. Cundick (*Graduate*), formerly an Engineer in the Flight Test Department, English Electric Co. Ltd., is now Senior Aerodynamicist with Folland Aircraft Ltd.

P. N. Dent (*Graduate*), formerly with Joseph Lucas (G.T.E.) Ltd., Burnley, is now a Technical Assistant with Rolls-Royce (Scottish Factories) Ltd.

The Hon. R. Q. Eden (*Associate Fellow*), formerly Research Engineer at Shell's Thornton Research Centre, is now in the Oil Product Development Dept., London.

J. L. Edwards (*Fellow*) of the de Havilland Engine Company has been appointed Chief Engineer, Gas Turbines.

J. F. Foss (*Associate Fellow*), formerly of Scottish Aviation Ltd., Prestwick, is to take up an appointment as Senior Engineer, Civil Aircraft Design Research team, with English Electric Co. Ltd. at Warton.

W. G. FitzGibbon (*Associate*), formerly with the de Havilland Aircraft Co. Ltd., has joined Canadair Ltd., Montreal, as Design Engineer "A."

J. M. Gray (*Fellow*), formerly Director of Civil Aircraft Research and Development, is now assisting Mr. Handel Davies, who is Deputy Director General on Future Systems, Ministry of Supply.

R. F. Jupp (*Associate*), formerly with Vickers-Armstrongs (Aircraft) Ltd., is now in the Development Section of Lansing Bagnall Ltd.

Lt. Cdr. R. A. Langley (*Associate Fellow*), formerly Deputy Project Officer for the Saunders-Roe F.177, is to take up a new appointment as Assistant Air Engineer Officer at R.N.A.S., Culdrose.

T. E. Marshall (*Associate Fellow*), formerly with Avro Aircraft, is now employed at Boeing Airplane Company, Transport Division, Renton, Washington, as a Designer.

P. Martin (*Associate*), formerly with A. V. Roe and Co. Ltd., is now with Avro Aircraft Ltd., Malton, Ontario.

R. B. Matthews (*Associate Fellow*), formerly with Dowty Fuel Systems Ltd., is now with Solar Aircraft Company of San Diego, U.S.A., as Analytical Engineer.

R. Middleton (*Associate Fellow*), formerly an Aerodynamics Technician with Folland Aircraft Co. Ltd., is now in the Aerodynamics Department of Boeing Airplane Company, Transport Division, at Renton, Seattle.

D. C. Minett (*Associate*), formerly Senior Examiner, Aeronautics, A.I.D. Department of Air, Melbourne, has taken a post as Production Planning Officer with the Standard Motor Co. (Australia) Ltd., Melbourne.

P. H. O. Pearson (*Student*) has joined Avro Aircraft Ltd., Ontario, as Junior Engineer in the Aerodynamics Department.

Squadron Leader F. M. PRICKETT (*Associate*), formerly with Fairey Aviation Co. Ltd., is now with the Directorate of Engineering, G.W., Air Ministry.

G. A. PULLINGER (*Associate Fellow*), formerly with Handley Page Ltd., is now a Section Leader, Aerodynamics, with Blackburn and General Aircraft Ltd., Brough.

G. E. SALT (*Graduate*), formerly with de Havilland Aircraft Co. Ltd., Hatfield, is now a Senior Designer (Flying Controls) with H. M. Hobson Ltd., Wolverhampton.

C. E. SPEDDING (*Graduate*), formerly with Saunders-Roe Ltd., is now a Senior Stressman with Folland Aircraft Ltd., Hamble.

Sir FREDERICK TYMMS (*Fellow*) was installed in October as Master of the Guild of Air Pilots and Air Navigators.

M. J. WEBBER (*Graduate*), formerly with the R.A.F., is now a test pilot with Bristol Aircraft Ltd.

P. WHITFORD (*Associate*), formerly at Prestwick Airport, has been appointed Airport Manager of the new Gatwick Airport.

Air Commodore Sir FRANK WHITTLE (*Honorary Fellow*), has been awarded the John Scott Award of America. The award has been made to such outstanding people as Orville Wright, Thomas Edison, Madame Curie, Guglielmo Marconi, Sir Alexander Fleming and Igor Sikorsky.

JOURNAL BINDING—NEW PRICES

The greatly increased postal rates, together with other rising costs, unfortunately necessitate revised charges for 1958 for the permanent binding of Journals. The increases will be 1s. 6d. on the 1957 volume and 2s. on previous volumes. The new charges will be:—

1957 Volume (including packing and postage *in the United Kingdom*)	£1 4s. 0d.
Previous Volumes (including packing and postage *in the United Kingdom*)	£1 6s. 0d.

Journals, with a note of the name and address of the sender, should be sent direct to The Lewes Press, Friars Walk, Lewes, Sussex, and the remittance to the Secretary at the Offices of the Society.

Members are asked to be certain that the address to which they want their Journals sent is the same on their letters to the Lewes Press and to the Society.

Self-Binder Cases

Self-Binder cases of the "Easibind" type to hold 12 Journals are available from the Offices of the Society at 11s. 6d. each.

CHANGES OF ADDRESS OR APPOINTMENT

To assist in keeping the records of members correct and up to date the Secretary will be glad if all members will notify him as soon as possible of changes of address. He would also like to know of any change of appointment.

When notifying changes please give the following particulars:—

Name (in block letters).	Grade of Membership.
New address (in block letters).	Old address.

New appointment.—Please give name and address of employer and position held.

Change of address must be received *before the 15th of the month* in order to be effective for the JOURNAL for the following month.

ELECTIONS

The following is a list of new members and transfers of membership of the Society:—

Associate Fellows

Said Abu-Mostafa (*from Associate*)
Geoffrey Brassington
Harold Brumby
Thomas Wight Campbell (*from Associate*)
Thomas Isaac Curl
David Pettit Davies
Harold James Elmore
John Sidney Thomas Finn
James Fletcher (*from Graduate*)
Arthur John Fuller
William Stanley Gibson (*from Associate*)
Glen Milton Hobday
John Maguire (*from Associate*)
Robert William John Stopes Parsons
Barry Radley
Ellis Pascoe Drake Tiddy
Barnes Winstanley Wallis (*from Graduate*)
Arthur Courtenay Watson
Albert John Watson
Leslie Robert Webb
Michael Sewell Wooding (*from Associate*)

Associates

Robert John Buckett
Henry Alfred Dovey Fairs
Brian Harry Heafford (*from Student*)
John William Herbert Howlett
Norman Melvin
Roger Mervyn Miles
Arthur Mortimer
Cyril Newby
John Ronald Sharp (*from Graduate*)

Graduates

Alan John Alexander
John Marles Herbert Barnard
Ronald George Carlton
John Barry Carr (*from Student*)
Alexander Coull
Bernard John Davey
James Dunwoody
Robert Paul Gerrand
Raymond Brian George Hedgecock
Walter George Hemming
Alec Stanley Hickerton
John Arthur Knivett (*from Student*)
Henry Julius Lee
John Anthony Lomax
Jonathan Hugh Armstrong Mason
David John Maull (*from Student*)
Kenneth Gerald Frank Noble (*from Student*)
Sydney Douglas Probert
Roger Hugh Moutray Richardson-Bunbury (*from Student*)
Bevan Ridehalgh
Henry Edward Stopher
Anthony Oldfield Wood
Michael James Wooldridge

Students

Jeremy Andrew Banham
Brian Michael Barber
Stanley Beighton
Samuel Colin Bendall
Gawain Hugh David Bradburn
Derek Fraser Cannell
John David Cannell
David Edward Clarke
Anthony John Dell
Stephen Guy Dru Drury
Roy Frederick Duggan
Christopher James Eaton
Norman Brian Fisher
Lyn Flook
John William Ford
Bruce George Edward Allen Foster
John Stewart Glen
John Trevor Green
Jeremy Frederick Haines
Clive William Hakney
Kenneth Brian Henwood Herbert
John Geoffrey Hicks
Peter Hind
Patrick Charles Holdorf
Kenneth Lloyd Horsman
Leonard William Illston
Alan Francis Jones
Michael John Douglas Knowles
Peter Lane
Raymond Leonard Langton
Michael Lisandro Lopez
Martin Vincent Lowson
Christopher James Marlow
John Stuart Masterson
David Mead
John Francis Anthony Nash
Aled Rees Pugh
Denis Francis Reardon
Peter William Richards
Peter Morgan Roderick
Denis Peter Sharp
Richard Francis Sims
David John Leslie Smith
Kenneth Robert Teare
David Stephen Thorn
Anthony John Turner
Nitindra Nath Upadhaya
Michael John Weeks
Philip Franklyn Wells
Michael John Woods
Roger Meyrick Woodward
Peter John Yorke

Companions

John Edwin Gwilliam
Benjamin John Frederick Muller
Gerald Robinson

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The Forty-Fifth Wilbur Wright Memorial Lecture

Advanced Education and Academic Research in Aeronautics

by

CLARK B. MILLIKAN, Ph.D., Hon.F.I.A.S., F.R.Ae.S.

(Director of the Guggenheim Aeronautical Laboratory, California Institute of Technology)

The Forty-Fifth Wilbur Wright Memorial Lecture, "Advanced Education and Academic Research in Aeronautics" was given before the Society by Dr. Clark B. Millikan, Hon.F.I.A.S., F.R.Ae.S., on 13th September 1957, at the Institution of Civil Engineers, Great George St., London, before a large and distinguished audience which included H.R.H. The Prince of the Netherlands and a number of the Americans who had attended the Sixth Anglo-American Aeronautical Conference. Sir George Edwards, C.B.E., B.Sc., F.R.Ae.S., President of the Society, presided. As has now become customary the principal awards of the Society awarded by the Council for the year were presented before the lecture (see July and October 1957 Journals). This year they included Honorary Fellowship of the Society which was accepted by His Royal Highness, The Prince of the Netherlands.

Introducing the Lecturer, Sir George Edwards said:—Dr. Millikan was born in Chicago in 1903, he graduated from Yale University in 1924 with the degree of Ph.B. and received a Ph.D. degree in physics and mathematics at the California Institute of Technology in 1928. In that year he was appointed Assistant Professor at the California Institute, in 1934 he became Assistant Professor, and since 1940 he has been a full Professor in the Aeronautics Department. He was a member of the Executive Committee of the Institute from 1945 to 1947 and was appointed Director of the Guggenheim Aeronautical Laboratory in 1949. He has been Director of Wind Tunnel Testing at the California Institute since 1935, and Director of the Southern California Cooperative Wind Tunnel since it began operations in 1945. He is Chairman of the C.I.T. Trustees Jet Propulsion Laboratory Committee.

A Fellow of the Royal Aeronautical Society and an Honorary Fellow of the Institute of the Aeronautical Sciences, of which he was President in 1937, he is also a member of a number of other Societies. In 1948 the British Government awarded him the King's Medal for Service in the Cause of Freedom, and in 1949 he received the United States Medal for Merit.

Dr. Millikan is currently serving as Chairman of the Scientific Advisory Committee to the U.S. Secretary of Defense and as Chairman of the Aircraft and Guided Missiles Panel of the U.S.A.F. Scientific Advisory Board. He is also a member of the Army's Ballistic Research Laboratories' Scientific Advisory Committee, Chairman of the Sub-Committee on Fluid Mechanics and a member of the Aerodynamics Committee of the National Advisory Committee for Aeronautics.

CLARK B. MILLIKAN
Ph.D., Hon.F.I.A.S., F.R.Ae.S.

1. Introduction

The forty-four Wilbur Wright Lectures which have been delivered to this Society have covered an astonishingly wide range of aeronautical subjects, reflecting the extraordinary extent of the areas on which aviation has had a profound impact during its short life of just over a half-century since the Wright Brothers' simple flying machine first brought to realisation man's age-old dream of flying like a bird. The category of Wilbur Wright Lectures having the largest number of titles is that of monographs on particular scientific or technical researches or fields. Only slightly smaller is the group of lectures discussing somewhat more generally aeronautical research facilities, techniques, and programmes. Third in the number of titles is the category related to the actual design and development of aircraft. Only one lecture, that of 1933 by Colonel F. P. Lahm, deals with aeronautical education and that in a rather restricted sense as its title, "Training the Aircraft Pilot," indicates. I propose to combine certain aspects of aeronautical education, research, and development to form the basis of my remarks. These aspects have been selected to fall within the compass of my thirty-odd years of experience in a rather special academic environment, and include the training of certain types of aeronautical scientists, engineers, and military officers, the researches which are associated with, and develop from, such an academic environment, and the direct contributions which this environment can furnish to the development of actual aircraft and missiles.

2. The Need for "Scientific Engineers"

Turning initially to the purely educational aspect, it appears useful to consider first the various needs which so obviously exist for engineers and scientists in the aeronautical field. Certainly largest in magnitude of the requirement is that of the industry which produces aircraft, missiles, power-plants, and all the myriad components which constitute a modern weapons- or aerial transportation-system. The imbalance between supply and demand for trained professionals in this area has been made painfully obvious during the past few years by the spectacular number of recruitment advertisements both in technical journals and in local daily newspapers, and the equally spectacular inducements these advertisements offer to prospective employees.

Perhaps less striking, and numerically smaller in persons required, is the need of the armed forces for officers with advanced technical training. The technological revolution in warfare, which has been proceeding at an accelerating pace since the First World War, now requires that military organisations have large numbers of officers with high technical and scientific competence and understanding, not only to monitor and select among their highly complex weapons systems under actual development, but also to look into the future wisely in a technical sense so as to sponsor the most promising and potentially useful military research programmes, and even establish future military requirements with a sound and imaginative estimate of capabilities based on scientific developments. In view of the increasing reliance the military are placing on civilian scientists, it is also essential that large numbers of officers have an understanding of, and sympathy for, such scientists, which can best be obtained through a period spent working with them during post-graduate study and research at civilian academic institutions. The military are very conscious of these requirements and are expanding their already considerable programmes of post-graduate civilian training of selected groups of their mature officers.

Still another urgent need for engineers, and especially scientists, exists in the research laboratories which have so greatly grown in number and scope during the past few years. The tremendous government laboratories with their immense and costly facilities, like those of the N.A.C.A. and Air Force in particular, are suffering badly for lack of enough highly-trained research workers. The numerous smaller laboratories operated for the government by non-profit institutions, and the increasing number of industry-owned laboratories which emphasise basic research, are also dependent for their effectiveness on a continuous supply of creative engineers and scientists who, with a few exceptions, must have experienced years of advanced training in the physical sciences.

Finally, it is essential for the long-range future that there be a steady output of highly trained and imaginative young men for the academic laboratories and schools which are primarily responsible for producing the scientists and engineers to satisfy all the other requirements, as well as their own.

This brief catalogue of demands makes it very evident that the aeronautical world requires, in addition to much larger numbers of "conventional" engineers, a very considerable supply of highly-trained professional men whose interest and experience are more oriented in the direction of basic science and research than has been traditional in engineering education. During the past 30 years a growing number of educational institutions in the United States has attempted to meet this need for qualified leaders in the more scientific aspects of aeronautical research, design, and construction. The basic requirements in the training of students to this end are obviously a strong emphasis on mathematics and the basic physical (including chemical) sciences, together with an immersion and active participation by the student in a creative research atmosphere. It is my firm conviction that, especially in the dynamic and swiftly changing aeronautical field, the desired objectives can most fully be attained if these basic requirements are satisfied in an environment where contact with the problems of industry and those of the governmental procurement and research agencies is close and continuing.

If the above premises regarding needs or requirements are accepted, a number of consequences appear to follow, determining the major characteristics of institutions attempting to fill these needs. First and most fundamental, is that the curriculum must be heavily weighted with courses in applied mathematics, the appropriate branches of physics, including mechanics, thermodynamics, electronics and circuit theory, and recently certain aspects of chemistry. Of equal importance are guidance, facilities, and time which make it possible for the student to engage in independent, although supervised, research. These two imply post-graduate study. In fact several of the aeronautics departments of the type under consideration, are entirely post-graduate ones, requiring a four-year undergraduate course as a prerequisite for admission. Most of those which do give undergraduate aeronautical degrees are placing increasing emphasis on their post-graduate work, as the demand for scientifically oriented aeronautical workers grows.

3. Meeting the Need

Considering for a moment undergraduate curricula, the increasing emphasis on basic and engineering science, which first occurred in aeronautics, is rapidly appearing in many other branches of engineering. A distinguished Committee on Evaluation of Engineering Education, of the American Society for Engineering Education (A.S.E.E.), recently made a three-year study and issued a report in June 1955. An important portion of this report considered in detail undergraduate engineering curricula and presented a suggested "Time Distribution for Scientifically Oriented Curricula." A number of my colleagues at sister universities and institutes have very kindly made available information on their undergraduate schedules, which I have

A.S.E.E. categories	*A.S.E.E. recommendation*	*Cal. Tech.*	*Instit. A*	*Instit. B*	*Instit. C*	*Instit. D*
(1) Humanities	20	23	18	16	19	16
(2) Math. and basic sciences	25	37	28	25	24	28
(3) Engineering sciences	25	29	19	24	29	19
(4) {Strictly aero. and design	25	9	30	32	19	23
(4) {inc. (4*a*) tech. background		(1)	(2)	(8)	(3)	(7)
(5) Electives	10	2	5 (inc. mil. sci.)	3	9 (inc. mil. sci.)	14 (inc. mil. sci.)

FIGURE 1. Percentage of Undergraduate time devoted to A.S.E.E. Committee categories in five Institutions awarding degrees in aeronautics.

attempted to put into a form which would permit comparison with the A.S.E.E. Committee recommendation. The categories chosen by the Committee are as follows:

(1) Humanistic and Social Studies.
(2) Mathematics and Basic Science (Physics and Chemistry).
(3) Engineering Science:
  (*a*) Solid Mechanics,
  (*b*) Fluid Mechanics,
  (*c*) Thermodynamics,
  (*d*) Transfer Mechanisms (heat, mass, and momentum),
  (*e*) Electrical Theory (fields, circuits, electronics),
  (*f*) Nature and Properties of Materials.
(4) Engineering Analysis, Design, and Systems (including the necessary technological background).
(5) Options or Electives in the above, or Research.

In fitting the various undergraduate aeronautical curricula into these categories all the strictly aeronautical subjects, in which the techniques and disciplines of categories (2) and (3) are applied to aeronautical problems, have been placed in category (4). Furthermore, a sub-category (4*a*), was introduced covering technological or manual subjects such as shop, drawing, classical machine design and mechanisms, and so on. The individual institutions, apart from the California Institute of Technology (Cal. Tech.), are not identified since the purpose is only to indicate general trends, and there might be disagreement as to the allocation of courses to the foregoing categories, where personal judgment necessarily had to be used. The results of the survey are given in Fig. 1.

A few explanatory remarks should be made relative to this table. The Committee pointed out that its percentages did not total 100. This was done to emphasise the approximate nature intended for their recommendations. Cal. Tech. gives no undergraduate aeronautical degree, but has an aeronautical option in the Engineering Division for students planning to go on to graduate study in the field. The other four institutions which do offer undergraduate aeronautical degrees also give post-graduate degrees, the relative emphasis on undergraduate and post-graduate work varying somewhat among the various schools. Three of the institutions offer military science, either as a required or an optional subject; this has been included in the Electives category as noted.

Perhaps the most striking feature of the table is the strong emphasis on the first three categories, both in the Committee recommendation and in the actual curricula. Twenty or twenty-five years ago the portion of the students' time devoted to such fundamental or background material would almost universally have been far smaller, and that assigned to more immediate or "practical" studies correspondingly greater. The technological or manual subjects, especially shop and drawing, which used to play an important role in engineering schools, have practically disappeared in many institutions, so as to give time for the additional scientific and background subjects.

The situation with regard to post-graduate curricula is neither so clear nor so easy to summarise. The differences in the courses listed in the various graduate school catalogues or bulletins are very wide, as is to be expected in view of the differences in the fields of specialisation of staff members at the various institutions. However, even here, some significant trends appear if one compares the current situation with that which obtained some years ago. In many schools the number of "design type" courses has greatly decreased, while that dealing with more analytical and scientific subjects has grown correspondingly. Also, in many cases where course titles have not changed, the viewpoint and approach have shifted from the "drawing board" or "practical" to the analytic and scientific.

The problems which the aeronautical engineer faces today in investigating interference effects, aerodynamic wing design at supersonic speeds, the effects of frictional heating on the structural and aeroelastic behaviour of high speed aircraft, combustion instability in air-breathing or rocket engines, or the re-entry of a hypersonic missile where dissociation and ionisation may occur at the bow shock, to cite only a few typical examples, require a mathematical skill and a thorough understanding of certain aspects of physics and chemistry which were entirely unnecessary only a few years ago. Something has had to give way in order to make it possible for the student to develop a familiarity with, and ability in, these disciplines, and the something has, in many cases, been the more practical or practising design type of subject.

The logical conclusion of these considerations is that, at least for some aeronautical graduate schools, the primary objective should be to turn out students with a broad enough mathematical and scientific background so that they are able to cope effectively with these, and

similar, complex and difficult problems. If such students are later to become designers in the classical sense they must learn the Art of Design while on the job with an aircraft company. Many professors feel that this is much the most efficient division of the training process between the academic and industrial members of the aeronautical community, and this feeling determines the educational policy of many aeronautical graduate schools, including that with which I am associated. However, it is only fair to say that the feeling is not universally held, and debates on the subject are frequent and heated on many campuses.

Correspondingly, in industry the consequences of this philosophy are understood by many, but by no means all, aircraft companies. The companies which do understand make provision for those of their younger engineers who have an interest and flair for Design to develop a proficiency in the Art during their work on the job. In other words, they have accepted the responsibility for this important aspect of the training and development of their creative designers, who actually constitute only a small percentage of their total technical staff.

There are, it seems to me, two fundamental conditions which must be fulfilled if such an educational programme, emphasising the analytical and scientific approach, is to be really effective. These are: a close contact with the actual producers in the field, both in industry and in the great governmental organisations, and a complete interweaving of classroom activities with an active and vital research programme. The first arises from the fact that aeronautics is in fact a branch of applied science, which accordingly becomes sterile if it is not keyed to really significant applications. The second is essential in any scientific field, whether pure or applied.

In connection with the first requirement of close contact with the "actual producers," there are a number of techniques which can be helpful. One is to have engineers from industry give formal courses or lectures on a part-time basis. It has been our experience that aircraft companies have been most co-operative in this connection. Another is to encourage participation by representatives of industry and governmental research laboratories in seminars where current problems, often in connection with the research programme, are discussed. This procedure is obviously greatly facilitated if the research programme involves matters of real interest to the visitors, which again emphasises the importance of such a programme.

Still a third technique is the part-time service of academic staff members as consultants to industry, or as members of the numerous scientific advisory committees of the various government agencies concerned with matters aeronautical. In connection with such activities there are certain difficulties and even dangers. The staff member must not become so involved in his consulting that his basic interest is diverted from the academic life, nor must his time become so occupied that contact with his students suffers. Furthermore, the company for which he consults must intelligently use his special capabilities (which all companies have not, unfortunately, learned to do). However, with the right kind of professor, and of company management, the consultant relationship has proved a most rewarding one for both participants, and has often led to a real enrichment of academic teaching and research. Similarly, service on the appropriate type of governmental scientific advisory committee can, for the academic man, both broaden his outlook and also keep him aware of the research and development problems which are of immediate importance and interest, to the benefit of his primary college job.

One additional kind of contact with "actual producers" is available at certain institutions which have assumed management responsibility for laboratories or special projects owned or supported by government or industry. Examples are Cal. Tech.'s Jet Propulsion Laboratory and Southern California Cooperative Wind Tunnel, which will be further discussed later. Analogous laboratories exist at many other institutions and can make important contributions to their purely academic programmes.

The other fundamental condition for an effective educational programme of the type under consideration is, as already mentioned, strong and creative research activity. The *sine qua non* in this connection is, of course, the calibre and interest of the staff members. It is almost always true that the most inspiring teachers in an advanced scientific field like ours are creative research workers. It is, therefore, a matter of primary importance, and of considerable difficulty, to create and maintain, in an aeronautical graduate school, an environment which will attract and hold such "*rarae aves.*"

There are, it seems to me, three requirements which must be satisfied in this connection. First, and basic to the others, is a university administration which appreciates the objectives and gives strong and sympathetic support to their attainment. Without this it is practically impossible to achieve either the necessary physical environment, or the even more essential intellectual atmosphere of dedicated scholarship. Second is a light classroom teaching load, so that the staff members may have ample time and energy for their own and their students' researches. This requires a ratio in numbers of faculty to students which is very much higher than would be considered normal where the professor's primary responsibility is formal classroom instruction. Finally, there is the provision of adequate laboratory facilities for experimental researches. Although ingenuity can often suggest methods of carrying out significant investigations with simple and even rudimentary equipment, it is none-theless true that, as flight speeds move from the subsonic up through the supersonic and into the hypersonic regimes, the complexity, power requirements, and cost of the laboratory facilities required for the pertinent experimental research studies increase tremendously.

4. Government Support of Academic Research

Both these requirements, for a high staff-to-student ratio and for elaborate laboratory facilities, mean that a

research programme of the type believed to be essential is extremely expensive. In view of the financial stringencies under which both state and privately supported universities have been operating, such research programmes would, in many cases, have been quite impossible had it not been for Federal Government support. The history of such support for basic aeronautical research in United States educational institutions, as it has developed since the Second World War, is not nearly so well known as it deserves to be. The story is a most interesting and an enormously important one, and although a really adequate treatment cannot be given within the scope of this lecture, a very sketchy survey is, perhaps, appropriate, and will be attempted.*

Before 1941 a few university research projects in aeronautics were supported by the N.A.C.A. and by certain laboratories and other sub-divisions of the Army and Navy. However, the total magnitude of these projects was extremely small and there was no overall programme or established set of procedures. During the war, practically the entire scientific potential of the United States was mobilised under what developed into the government's Office of Scientific Research and Development, the famous O.S.R.D. headed by Dr. Vannevar Bush. This wartime experience for the first time gave many academic scientists and engineers an awareness of, and contact with, the innumerable and growing technical problems of the country's Defense Establishment and, even more important, indicated to high level Army and Navy leaders their extreme dependence on technology and even fundamental science. This dependence was in no area more clearly apparent than in that of aerial warfare which was developing with an almost explosive violence.

Even before the end of the war it had been determined that the O.S.R.D. would not be continued as a peace-time agency of the government. Thus, at the war's end, the Defense Establishment's need for assistance from civilian scientists had been established, scientists were returning to their academic laboratories where they were searching for financial support for their increasingly expensive research projects and the one government agency which was competent and able to arrange for the satisfying of these two needs was being disbanded. At this critical juncture the Navy Department made a decision of the utmost importance: it proposed to the Congress the establishment of an Office of Naval Research (O.N.R.) which was to have as one of its primary functions the support of research in universities. The Congress enacted the necessary legislation and on 1st August 1946 the President signed Public Law 588, which was an act: "To establish an Office of Naval Research in the Department of the Navy; to plan, foster, and encourage scientific research in recognition of its paramount importance as related to the maintenance of future naval power, and the preservation of national security; . . . ." For some five years the O.N.R. was the one agency of the Department of Defense with the explicitly stated responsibility for supporting basic scientific research in academic institutions, and during this period were invented and established many of the concepts which have been found to be essential if such a relation between government and universities is to work smoothly and effectively. A little later we shall consider the pattern which has evolved in this connection.

In June 1951 the Office of Ordnance Research (O.O.R.) was established by the Army's Ordnance Corps with the primary mission of "supporting basic research in fields fundamental to Ordnance technology." Since that time it has served as the Army's agency specifically concerned with the support of university research in the "mathematical, physical, chemical, and metallurgical and engineering sciences." Unlike all the other government agencies under consideration, whose headquarters are in Washington, the O.O.R. has established its headquarters on the campus of Duke University at Durham, North Carolina.

The Air Force, in 1951, established the Air Research and Development Command (A.R.D.C.) as one of its major Commands and in September of that year formed the Office of Scientific Research (O.S.R.) as a part of the A.R.D.C. headquarters staff. In August 1955 the O.S.R. became a separate field organisation of the Command. It furnishes the major Air Force support of academic research in carrying out its mission to "plan, formulate and manage the exploratory research program for the Air Force that will insure maximum strength and efficient use of the strategic scientific potential of the United States and its allies in support of air technology." In this statement "exploratory" is essentially equivalent to "basic" in that it refers to research conducted without a specific end item in view, but rather with the aim of "increasing the sum total of human knowledge in areas of interest to the Air Force." It will be noted that the scientific potential of the United States' allies is specifically mentioned, and the O.S.R. accordingly supports academic research abroad as well as at home.

The National Science Foundation (N.S.F.) was established by Congress in 1950 with major responsibility for the support of basic research in the sciences. In carrying out this responsibility it makes grants to university investigators which are analogous to the research contracts awarded by the three Department of Defense Research Offices. However, in addition, it has a large fellowship programme for the support of graduate students in science; in this respect it is unique among the government agencies supporting science. Both N.S.F. programmes got under way in 1951-52 and have grown rapidly in succeeding years.

The fifth of the government agencies which make major contributions to the support of academic research in aeronautics is the National Advisory Committee for Aeronautics (N.A.C.A.). Its history in this respect is far longer than that of the other four. In fact the first technical report issued by the N.A.C.A., shortly after

*In this connection, I must express my deep gratitude to the scientific directors of the major government agencies involved who most kindly, and I am afraid, at the expense of considerable trouble, made available most of the data on which this survey rests.

its establishment in 1915 as an independent government agency reporting to the President, covered work done at the Massachusetts Institute of Technology under the direction of Professors J. C. Hunsaker and E. B. Wilson. At the time the N.A.C.A. had no facilities of its own where research could be conducted. However, by 1920 the Langley Laboratory was in operation, and thereafter the major portion of the N.A.C.A.'s resources was devoted to research in its own laboratories. A small programme of sponsored research in universities was, nevertheless, continuously maintained. After the Second World War this programme was somewhat more formalised administratively, and by 1950 had reached essentially the magnitude which it has since maintained, and which is considerably smaller than those of the other four agencies.

Before discussing the current nature of these five programmes in somewhat more detail, it may be well to consider the general pattern which has evolved and which is more or less common to all. First, and most important, is that the research projects supported are practically universally unclassified (from the military security standpoint), as is only proper if they have a basic scientific character and are not directed toward development of end-items. A corollary to this is that presentation of results to scientific meetings and publication in technical journals is encouraged. The N.A.C.A. publishes its own series of technical reports in which results of its sponsored researches normally appear, and the Air Force also issues technical publications which are available, but in general, results are published in the established scientific journals, or in Proceedings covering conferences or symposia, acknowledgement of the sponsoring agency being, of course, included. Most of the agencies in question also sponsor special symposia from time to time, and modest allowances for travel to these and other scientific meetings are usually included in individual research project budgets.

Much thought and effort has gone into the development of suitable fiscal and legal procedures. The N.A.C.A. has always used the research contract technique, but as an independent government agency it has been able to keep the restrictions and "red tape" to a minimum, so that its university contracts are actually administered very much like simple "grants-in-aid." The small number of projects supported by the Army and Navy before the war, were forced to employ the technique of procurement contracts whose form and provisions had developed over many years in connection with the purchase of items from industry. Such contracts were completely unsuited to the support of research investigations carried out by non-profit institutions, and much confusion and superfluous labour resulted. Special emergency procedures were worked out by the O.S.R.D. which solved the problem during war-time but could not be carried over directly into peace-time operations. In particular the question of the inclusion in research contracts of funds to cover the indirect or overhead costs to the university was an especially thorny one. Secretary of Defense Forrestal was largely instrumental, after the war, in having a formula developed covering such overhead cost reimbursement. This was adopted in 1947 by the Department of Defense and a large group of universities, and has been used ever since by the three military services. The matter is again under review at present by a high level government committee with the hope that a common formula and procedure may be adopted for all government agencies engaged in the support of academic research. In any case contractual and fiscal procedures have been worked out which very satisfactorily furnish the framework within which this new and very special government activity can be carried on.

Turning now to the five indvidual programmes as they are currently functioning, I shall consider them in the order followed above in the brief historical summary. In the O.N.R. the Assistant Chief for Research and his Science Director are responsible for the university contract research programme which is divided into seven divisions covering the Mathematical, Physical, Material, Earth, Biological, Psychological, and Naval Sciences. The total contract programme for the 1957 fiscal year had a dollar volume of some $42,000,000 of which nearly $12,000,000 were spent in areas closely related to the aeronautical field. The total number of such aeronautical projects is a little over 300, involving nearly 450 university staff members and some 500 graduate students. These projects are found largely in the Mathematical, Material, and Physical Sciences Divisions. The first is responsible for investigations in Applied Mathematics and Mechanics, the latter including fluid and solid mechanics, heat transfer, and so on. The Material Sciences Division includes metallurgy, chemistry, and power, in the last of which are found combustion and other propulsion problems. Under the Physical Sciences Division are included nuclear, electronic, and molecular studies, especially those leading to an understanding of momentum and heat transport processes in gases. Two important long-range research programmes which have been sponsored over a period of years by the Mechanics Branch are, the development of shock tube techniques and their application to many diverse problems in gas dynamics, and an intensive study of rarefied gas phenomena in the region between the free molecule and continuum flow regimes. These two projects were initiated in 1951 and have been continuously supported ever since. Both have had important impacts on current aerodynamic thinking and research activity. O.N.R. has sponsored numerous other very basic and long-range programmes, as well as a numerically larger group of studies more closely related to immediate aeronautical problems.

The Office of Ordnance Research of the Army during the fiscal year 1957 supported a basic research programme at about a $4,000,000 level. This covered some 350 projects at 125 colleges, universities, and research institutes, and supported nearly 400 senior scientists, about 65 post-doctoral fellows, and some 1,000 graduate students. Only a small percentage of this support is applied to strictly aeronautical projects, as is natural in view of the many other scientific fields which underlie the problems of Ordnance. However, O.O.R. does contribute significantly to studies in the

Government agency	Dollar volume (millions)	Institutions supported	Individual projects supported	Staff members and grad. students supported
Total programme				
O.N.R. (Navy)	42·5	204	1622	3300 (approx.)
O.S.R. (Air Force)	16·4	250	650	900
O.O.R. (Army)	3·8	125	350	1350
N.A.C.A.	0·7	20	45	170
N.S.F. (Math., Phys., Eng. Sciences)	8	—	570 (approx.)	1800 (approx.) (including fellowship programme)
Total	71·4	—	3240 (approx.)	7500 (approx.)
Aeronautics and closely related fields				
O.N.R. (Navy)	11·8	—	307	950
O.S.R. (Air Force)	6	90 (approx.)	240 (approx.)	330 (approx.)
O.O.R. (Army)	0·2	—	8	50 (approx.)
N.A.C.A.	0·7	20	45	170
Total	18·7	—	600 (approx.)	1500 (approx.)

FIGURE 2. Support of Academic research by Government Agencies.

mathematics of flow dynamics, and in various aspects of experimental fluid mechanics such as blast phenomena, shock interaction, Magnus effect, and hypersonic flows. It has played an important role in introducing scientists, who would otherwise have been unaware of them, to the manifold problems involved in modern Army Ordnance.

The Air Force Office of Scientific Research has set up four Directorates to manage its programme of sponsored, exploratory research: Aeronautical, Physical, Material, and Bio-Sciences. The Aeronautical Sciences Directorate includes three Divisions covering Mechanics, Mathematics, and Combustion Dynamics, and has responsibility for most of the projects which fall within the conventional aeronautical area. The total sponsored research programme for the fiscal year 1957 had a dollar volume of over $16,000,000 which was assigned to about 650 individual projects in some 250 different institutions. The O.S.R. estimates that between 800 and 1,000 university staff members and graduate students are supported by these projects. Something over a third of the entire programme involves projects of a direct aeronautical character, while the remainder is in more indirectly related scientific areas. The range of individual subjects covered is extremely broad. In fluid mechanics, one of the major fields of O.S.R. interest, great emphasis has been placed on real gas effects: compressibility, viscosity, turbulence, and so on. For example, the rarefied gas programme mentioned above is carried on under joint sponsorship of O.N.R. and O.S.R. There are many other projects in a wide variety of scientific fields which reflect the large and growing interest of the Air Force in problems related to all aspects of space flight.

The National Science Foundation programme of research grants in the field of our interest is administered by its Mathematical Physical, and Engineering Sciences Division, while graduate fellowships are handled by the Scientific Personnel and Education Division. For the fiscal year 1957 these research grants totalled some $8,000,000 while the number of graduate fellowships was nearly 600. Both of these figures correspond to the entire range of disciplines included in the Mathematical, Physical, and Engineering Sciences, and the fraction assignable to fields related to aeronautics is almost certainly very small. The contribution is, however, an appreciable one and may well increase in the future as the scope of the N.S.F. activities continues to grow as it has during the past few years.

As mentioned already, the history of the N.A.C.A.'s support of research in universities is far longer than that of the other government agencies here considered. Although it is on a relatively modest scale, approximately $700,000 for each of the past few years, the programme has proved an extremely valuable one. Each year the N.A.C.A. contracts for about 45 research investigations at some 20 academic institutions. Many of the projects are carried on for several years and these longer range programmes have frequently made important contributions to aeronautical science. Examples are: improvements in high temperature alloys, fundamentals of transonic flows, compressor stall phenomena, helicopter rotor flow fields, and buckling of circular cylinders.

It is difficult to find common bases of comparison of these five programmes so as to furnish an overall picture of their combined magnitude and significance. This is primarily because of the differences in the fields of interest of the various agencies, and the associated

differences in the available statistics. An attempt has, nevertheless, been made in the two tables of Fig. 2 to present such a picture on the basis of the available figures, which are not, in all cases, precise or complete. It is hoped that the tables will at least furnish a reasonable estimate of the contribution which these federal agencies have made during the past fiscal year to American graduate study and research in general, and to their more specialised aeronautical aspects in particular.

It is apparent that the contribution of this overall programme to basic aeronautical research and graduate student training has been a tremendous one. In fact both their present pattern and scope would have been quite impossible without this government support. There is now general agreement that basic physical research and the development of highly trained workers is of such importance to the nation that strong support for them is a proper function of government. Questions are sometimes raised, however, as to the desirability of having such support furnished by multiple agencies as described above, rather than by a single federal organisation.

It is my own, strongly held, view, which is shared by many others who have studied the problem, that single-agency support would be far less desirable for many reasons. Considering the matter first from the viewpoint of the sponsoring agencies, the distinguished physicist I. Rabi has presented* the following cogent arguments for support of basic research by the three military departments which constitute the operating agencies of the Department of Defense.

> "The Department of Defense requires the most advanced technology much more than civilian industry does. Its technical problems are greater than those posed by the civilian technology. It always operates in its development program at the limit of known science. The Department of Defense cannot therefore entrust the responsibility for scientific progress entirely to other agencies which are not aware of its desperate necessities.
>
> "Secondly, the Department of Defense must see to it that the United States is in the very forefront of science in order to protect its vast investment and the security of the U.S. against technological surprise and to avoid obsolescence. The whole defense system of a country can be outflanked by a new scientific advance such as atomic weapons or radar when this equipment is not a part of its arsenal.
>
> "Thirdly, the Department of Defense must support basic research in order that its body of officers and civilians are kept continually aware of scientific advance. It can remain in close contact with growing science only by being vitally concerned with basic research as a part of a routine activity through awarding of contracts, justification of budgets and programs, etc. . . . ."

*In the Introduction to a report "Basic Research in Electronics" prepared for the Assistant Secretary of Defense (Research and Development) in May 1956.

The N.A.C.A. in carrying out its assigned mission "—to supervise and direct the scientific study of the problems of flight—" has found its relatively small programme of research support in universities of the highest value in its own operations, in view of the contacts and associations between its staff and those of leading academic institutions which this programme provides.

Finally, the National Science Foundation in fulfilling its role of general support for science finds it desirable to establish and maintain contact with those broad areas which are of especial concern in aeronautics.

From the viewpoint of the institutions supported, the multiple sponsorship of research is also highly desirable. A single agency—in effect a Czar—having the sole responsibility for a nation-wide programme, could hardly avoid developing rigidities, biases, and blind-spots which would inevitably restrict a broad programme of basic research. The contacts which academic persons develop with members of the supporting government agencies, and with the scientific and technical problems with which the latter are concerned, are also of great value in connection with both research and teaching activities.

In summary, the programme of government support of university research which has developed in the past decade, and especially in the past five years, has clearly become one of the major factors in maintaining the essential supply of highly trained scientists and engineers which the country requires for the continued development of both its civil and military aviation. This programme is also essential for keeping filled the reservoir of fundamental scientific knowledge and understanding from which future technical developments can be drawn. It has been created and developed by far-sighted and dedicated leaders. Its effective continuation will require successors having the same qualities, to ensure that the relatively modest funds for its support are not eliminated or diverted to more immediate and short-range objectives, which are

FIGURE 3. Panel flutter model with controllable flutter amplitude installed in the J.P.L. 12 in. supersonic tunnel for test.

perhaps easier to justify to Congressional Appropriations Committees and to administrators responsible for the allocation of limited Research and Development funds.

5. Industry Support

During recent years the aeronautical industry has begun increasingly to demonstrate an awareness of its responsibility for the training of young engineers and scientists and for the encouragement of the basic sciences which underlie its technical progress. Most of the major companies now have fellowship programmes in connection with institutions offering aeronautical curricula. There have also been significant contributions to colleges in support of special educational projects and facilities such as wind tunnels, special laboratory facilities, libraries, and so on. Figures kindly made available to me by the Aircraft Industries Association indicate that in the academic year 1955-56 the industry's scholarship and fellowship programme totalled some $1,600,000, while the grants for specific projects came to $1,100,000. For the past year these amounts were appreciably larger, although the actual figures have not been compiled.

Very recently some of the larger companies have been exploring the possibility of supporting individual researches in much the same manner as has proved so effective in the case of the government grants and research contracts discussed earlier. It appears that this programme will almost certainly become a major one in the future.

Summarising again, industrial support of advanced aeronautical education and research has already reached a considerable magnitude, although still small compared with the total provided by government agencies. However, industrial leaders are now aware of, and much concerned with, the problem and it is apparent that the scope of such industrial assistance will increase rapidly during the next few years.

FIGURE 4. Two test specimens included in the study of general instability of ring-stiffened cylinders.

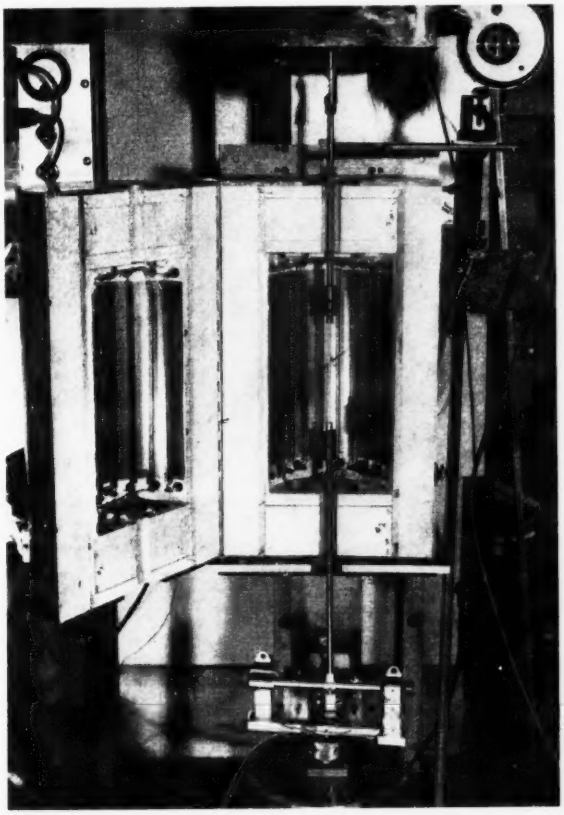

FIGURE 5. Metal fatigue apparatus with oven opened to show a test specimen.

6. Illustrative Examples

Until this point the present talk has not followed the tradition of recent Wilbur Wright Lectures in at least one important respect: it has involved almost no slides, and certainly none possessing any pictorial interest. To remedy this defect I propose in this final section of the

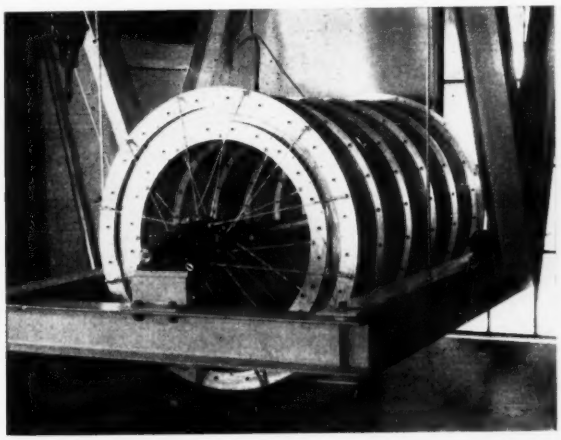

FIGURE 6. Rotating cylinder apparatus for the study of circular Couette flow.

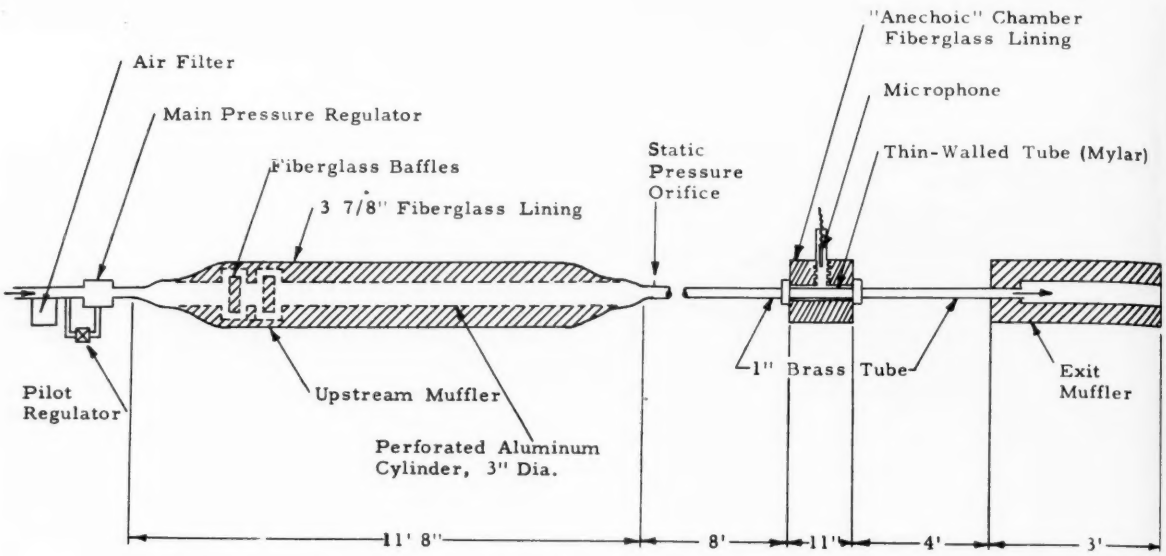

FIGURE 7. Diagram of the apparatus for studying noise produced by turbulent flow over a solid surface.

paper to present a few examples giving visible evidence of the results of government and industrial support of three facilities at the institution with which I have the privilege of being associated. These three very different laboratories are the Guggenheim Aeronautical Laboratory (G.A.L.C.I.T.) which houses our graduate school of aeronautics, the Southern California Cooperative Wind Tunnel (C.W.T.), an industry-owned facility, and the Jet Propulsion Laboratory (J.P.L.), operated by Cal. Tech. for the United States government. The emphasis will be on physical facilities and apparatus, and on the problem areas in which they are used, rather than on detailed results obtained. Accordingly only experimental activities will be touched on while the equally, or even more, important theoretical endeavours are, for this purpose, ignored.

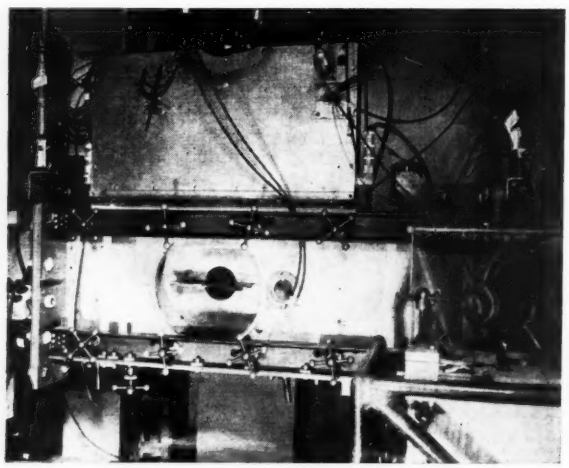

FIGURE 8. Flat plate with cut-out in the transonic wind tunnel.

7. The G.A.L.C.I.T.

Considering first the G.A.L.C.I.T., I have selected a few examples in solid and fluid mechanics upon which our staff and graduate students have been working during the past few years, and which have been supported by one or another of the agencies discussed earlier. Professor Y. C. Fung has been directing a continuing study of panel flutter supported by the Air Force Office of Scientific Research. Both the flutter stability boundaries and the large amplitude fluttering motion have been studied. Experiments have been performed in the G.A.L.C.I.T. 4 in. × 10 in. transonic wind tunnel, in the small two-and-a-half in. Mach number of 4 supersonic tunnel, and also in the J.P.L. 12 in. supersonic tunnel. Fig. 3 shows a panel with controllable flutter amplitude installed for test in the J.P.L. tunnel. This, incidentally, furnishes a good example of the mutual support which the two laboratories furnish one another.

Professor E. E. Sechler has supervised two solid mechanics programmes, the first being an investigation of the basic general instability criteria for ring stiffened cylinders. Certain missile structures call for cylinders stiffened only by rings and without longitudinal members. Fig. 4 shows two of a large family of such cylinders which have been tested, and clearly indicates the interesting types of failure pattern which are observed. This study has been supported by the Ramo-Wooldridge Corporation. Dr. Sechler's second programme, sponsored by the N.A.C.A. is an investigation of the fundamental parameters underlying the fatigue of metals. Attention has been directed to the relationship between internal damping (as measured by a long rod used as a torsion pendulum) and temperature, stress, frequency of stress application, and number of stress cycles. Inter-crystalline slip changes the internal damping and thus furnishes a measure of fatigue

FIGURE 9. Acoustic field radiated from a cut-out at $M=0{\cdot}8$.

FIGURE 10. Apparatus for the study of cylindrical shocks produced by exploding wires.

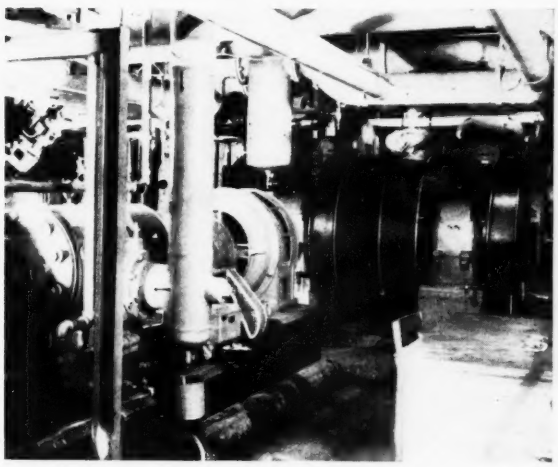

FIGURE 12 (*right*). A small portion of the hypersonic tunnel compressor plant.

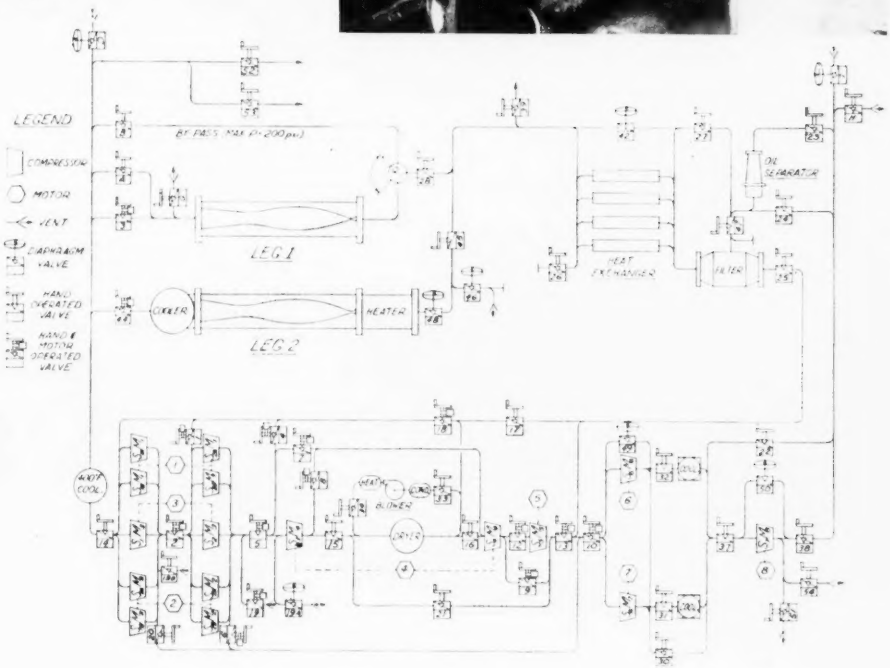

FIGURE 11. Schematic diagram of the G.A.L.C.I.T. hypersonic wind tunnel facility.

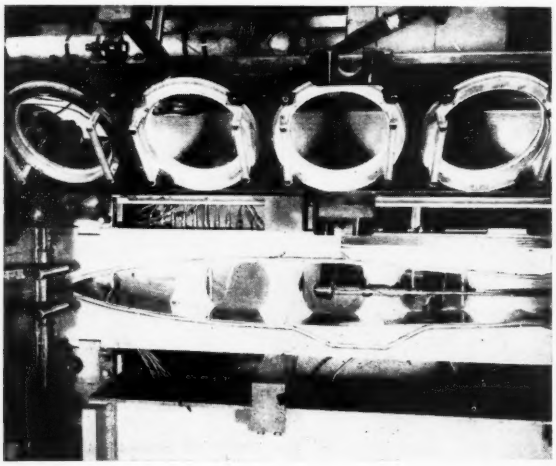

FIGURE 13. $M=5{\cdot}8$, Leg 1 hypersonic test section with side plate removed and model installed.

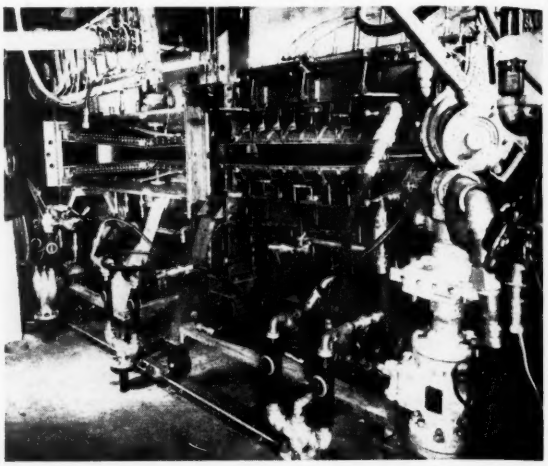

FIGURE 14. Variable Mach number, water-cooled Leg 2 hypersonic nozzle, test section and diffuser, with side plates removed.

damage. Fig. 5 shows the experimental set-up with the controlled temperature oven opened to show a test specimen.

In fluid mechanics the examples chosen cover the range of Mach numbers from the essentially incompressible to the hypersonic regimes. Professor Donald Coles is studying stability and transition in circular Couette flow with the support of the National Science Foundation. The apparatus he has developed, shown in Fig. 6, comprises two concentric, approximately 3 ft. diameter, cylinders whose rotation can be independently and very accurately controlled. Hot wire techniques are employed and special attention has been given to the stability of the irrotational vortex motion, and to the case with rotating outer cylinder where Taylor instability does not occur.

In the intermediate Mach number range three programmes are being carried on by graduate students under Professor H. W. Liepmann's direction. The first, a study of the noise produced by turbulent boundary layers flowing over solid surfaces is sponsored by the N.A.C.A. In one experiment the fluctuating forces exerted on a wall by a high speed turbulent boundary layer are measured with piezo-electric pickups. In a second, a low noise level turbulent pipe flow passes through a very thin-walled (down to 0·001 in.) cellophane tube. The acoustic field is measured in a heavily insulated chamber surrounding this tube. This rather unusual apparatus is shown in the line drawing of Fig. 7; unfortunately the dimensions made it impossible to obtain an adequate photograph.

The second programme, also supported by the N.A.C.A., is a study of acoustic radiation from cut-outs in aerodynamic surfaces, and was recently completed. Fig. 8 shows a flat plate, with small rectangular cut-out, mounted in the 4 in. × 10 in. transonic wind tunnel. Incidentally, this tunnel was originally constructed with Air Force support for the investigation of shock wave-boundary layer interaction and was used for several years in studying transonic similarity phenomena. Fig. 9 is a schlieren spark photograph showing the acoustic field radiated from the cut-out at a Mach number of about 0·8.

The third of Dr. Liepmann's studies deals with cylindrical shock waves and is supported by the Office of Naval Research. Fig. 10 is a photograph of the apparatus, which is essentially a lucite circular cylinder along whose axis a thin wire is exploded by a powerful electric discharge. A cylindrical shock, initially very strong, travels outward to the wall and is then reflected back to the centre. Here it reflects again and the process is repeated. It is hoped that it may be possible to re-energise the shock by repeated discharges through the ionised gas region along the axis.

Turning finally to the high Mach number area, the Army Ordnance Corps has for many years supported the design, construction, and research operation of a small hypersonic wind tunnel facility. The compressor plant required for continuous operation of a wind tunnel at Mach numbers up to 10 is necessarily extremely complex and elaborate. Fig. 11 is a line diagram of the seven stage installation at the G.A.L.C.I.T. and Fig. 12 shows a small section of the compressor room with rotary vane type and reciprocating stages visible. The closed circuit can be completed by either of two test sections, called Legs 1 and 2, each having a cross-section about 6 in. × 6 in. Leg 1 has a maximum stagnation temperature of about 300°F and fixed nozzle blocks giving a Mach number of 5·8. Fig. 13 shows a blunt body model mounted in Leg 1 with one nozzle side plate removed. Leg 2 includes an electric heater giving a maximum stagnation temperature of about 1,150°F which should permit condensation-free operation up to Mach numbers of 9 or 10. This high temperature requires that the throat, adjustable nozzle, test section, and diffuser be water-cooled, and results in an extremely complex installation. Fig. 14 shows this Leg 2, which was constructed by the Jet Propulsion Laboratory as a scale model for a larger hypersonic

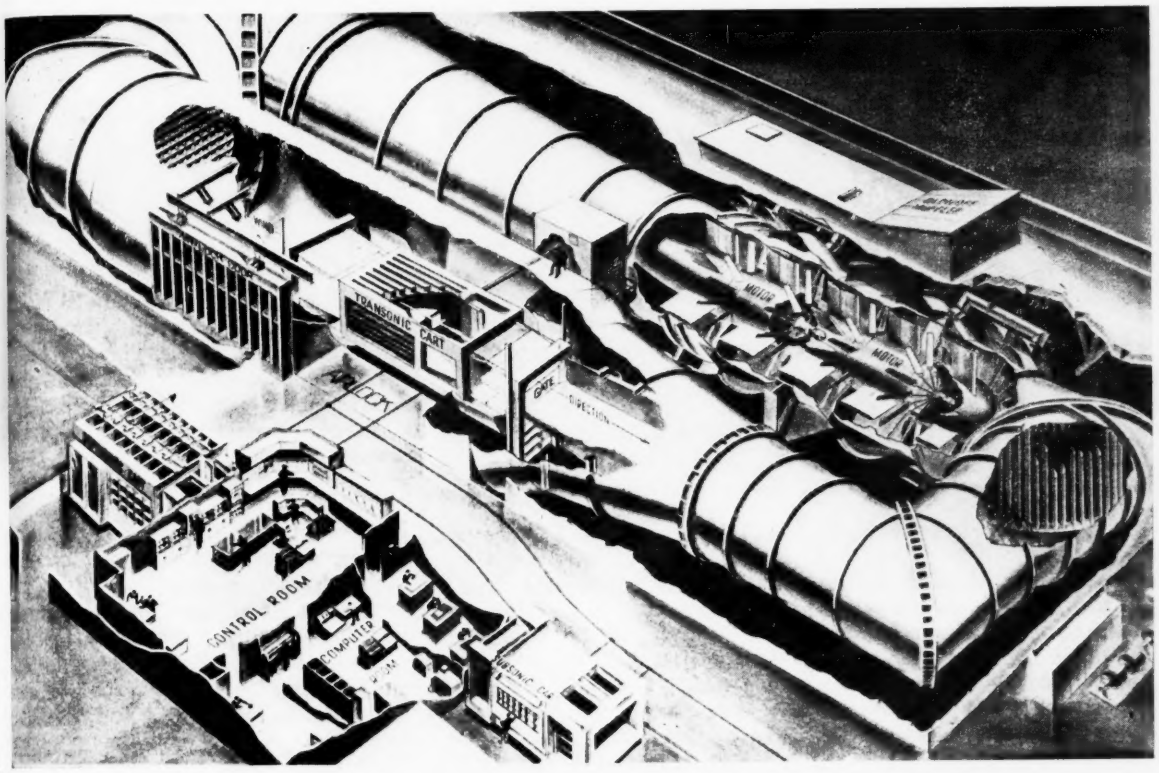

FIGURE 15. Cut-away diagram of the C.W.T.

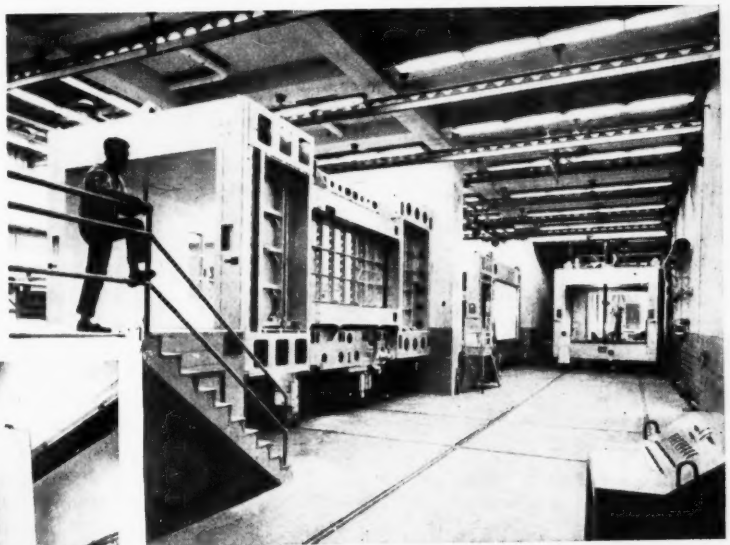

FIGURE 16. Three interchangeable test sections or carts in the model shop area just outside the tunnel.

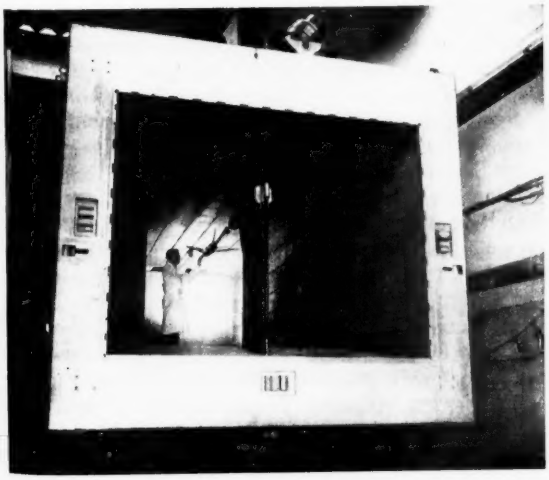

FIGURE 17 (*left*). Sting-mounted model being adjusted in the slotted, transonic test section. (The adjustable flaps at the downstream end are not in their operating positions.)

FIGURE 18. Control room of the C.W.T.

tunnel, to be mentioned later. The photograph shows the model tunnel during its initial test and calibration. Under the supervision of Professor Lester Lees and other staff members, numerous investigations have been undertaken in Leg 1 and earlier versions of Leg 2. Some of the subjects studied under the available hypersonic flow conditions have been flat plate boundary layer characteristics (including skin friction, heat transfer, and laminar-to-turbulent transition), heat transfer to figures of revolution using both transient and steady state techniques, thick boundary layers on thin circular cylinders in axial flow, film cooling, flow fields around both slender and blunt figures of revolution, and so on. These investigations, like all of the others cited as examples, have been made possible by the support afforded academic research by the various agencies mentioned.

8. The Cooperative Wind Tunnel

The Cooperative Wind Tunnel was conceived, designed, and constructed during the Second World War by Cal. Tech. for the Convair, Douglas, Lockheed, and North American airframe companies, each of which owned its own undivided interest. It was placed in operation in 1945 as a large subsonic ($M=0{\cdot}95$) 12,000 h.p. facility whose primary function was the development testing of new aircraft. In 1948 the ownership base was broadened when McDonnell Aircraft of St. Louis acquired an interest. By 1949 it was becoming clear that aircraft flight speeds would shortly be pushing into the supersonic range, and an urgent need for transonic test data was developing. Not long thereafter, on the basis of a careful preliminary design study, the Owner Companies in 1951 authorised a major alteration programme which would raise the installed horsepower to 40,000 and increase the speed to a Mach number of 1·8. The alteration programme involved replacement of two major tunnel sections, the fan section and the test section. To avoid a long and costly shutdown of the facility, complete new sections were prefabricated, including installation and checkout of all equipment, wiring, and plumbing. On 1st February, 1955, the tunnel was shut down, the old sections were scrapped, the new sections were moved into place, the tunnel was reconnected, and flow calibrations and adjustments were made. Routine development testing was resumed on 1st November 1955, just nine months after the shut-down date. Since starting operations the tunnel has operated without major interruption on a two-shift basis and the demand for testing time has always exceeded that available. The total investment of the owner companies now amounts to some $12,000,000 and the replacement cost of the facility under present conditions would far exceed this amount.

FIGURE 19. The first J.A.T.O. flight in the United States.

Figure 15 is a cutaway diagram showing the principal features of the tunnel in its present configuration. Fig. 16 shows the three interchangeable test sections or carts, one with fixed, solid walls for subsonic tests, one with slotted walls for the transonic region, and the third with flexible and adjustable floor and ceiling forming a Laval nozzle for supersonic flows. Fig. 17 shows a sting-mounted model containing an internal strain gauge balance being adjusted for test in the transonic test section. Fig. 18 is a view of the control room showing the operating consoles and the cabinets containing devices which translate the signals from the data-gathering transducers into digital form. These digitised signals are then transmitted to a high speed computer in the next room, where all the computations leading to final dimensionless coefficients are carried out. Thus within a few seconds of the time the data-gathering button is pushed, the final results are available for the inspection of the test project engineer.

Although the primary purpose of the C.W.T. is

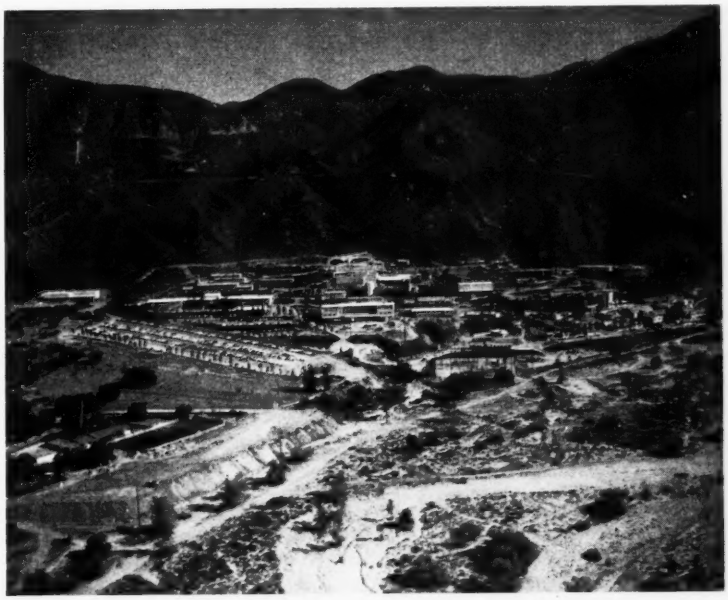

FIGURE 20. Aerial view of the Jet Propulsion Laboratory.

non-academic, close contact is maintained between it and the G.A.L.C.I.T. Academic staff members serve as consultants, many of the senior C.W.T. staff members have come from the Cal. Tech. Aeronautics Department, several graduate students are employed on a part-time basis, and a number of C.W.T.-sponsored fellowships for graduate study are available to employees. Furthermore, a portion of the C.W.T. budget and testing time is allocated to research projects which may be associated with graduate student thesis work. It is believed that this close association has been of great mutual benefit to both activities.

9. The Jet Propulsion Laboratory

My last example, the Jet Propulsion Laboratory, is a much larger scale operation than the other two. It has grown from an extremely modest beginning in 1936, when a few graduate students at the G.A.L.C.I.T. initiated studies of rocket power plants and rocket-propelled vehicles. In 1939, at the instigation of General H. H. Arnold, the Army Air Corps undertook the sponsorship of the programme, a few acres of land were purchased in the Arroyo Seco in the foothills just north of Pasadena, where rocket experiments could be conducted with more convenience and less hazard than on the Cal. Tech. campus, and the Army Air Corps Jet Propulsion Research Project was established with Dr. Theodore von Kármán, then Director of the G.A.L.C.I.T., as its first director. For the next few years the chief emphasis was on the development of solid and liquid propellant rockets for Jet Assisted Take-Off (J.A.T.O.) of aircraft. In 1941 the first successful J.A.T.O. flights in the United States were accomplished with small solid propellant rockets on an Ercoupe monoplane (*see* Fig. 19). The following year a Douglas A-20A bomber was fitted with two much larger liquid propellant rockets and made numerous highly successful J.A.T.O. flights. At the direction of the Air Corps the Aerojet Engineering Corporation was established to undertake the manufacture and commercial development of these J.A.T.O. units, and the G.A.L.C.I.T. group turned its attention to other jet propulsion researches, which rapidly expanded in scope. The Army Ordnance Corps requested that the results of these researches be applied to the development of rocket-propelled ballistic missiles. This soon became the central core of the project's varied activities, and in 1944 a re-organisation was effected whereby Army Ordnance took over ownership and sponsorship of the project which was then established as the Jet Propulsion Laboratory. In the past 15 years its growth has been quite extraordinary until now it occupies 80 acres and employs some 1,900 persons of whom nearly 30 per cent are professional engineers and scientists. Fig. 20 is a recent aerial view of the laboratory which gives an indication of its location and size.

Some idea of the scope of J.P.L.'s research and development activities can be obtained from the titles of the seven divisions within which the work is conducted: Aerodynamics, Propellants, Design, Liquid Propulsion Systems, Guidance, Instrumentation, and Systems Engineering. In the time remaining it would be quite impossible even to list the extremely varied problem areas which are under study, and I shall accordingly limit myself to a brief survey of the specific missile development programme which has been carried on continuously since the Laboratory was established.

The first J.P.L. missile was an uncontrolled solid propellant rocket called the Private A. It was launched by a solid propellant booster, stabilised by fixed fins, and powered by a motor giving a 1,000 lb. thrust for 30 seconds. Its flights, starting in 1944, provided valuable aerodynamic data. The second missile, called the WAC Corporal, was designed to carry a 25 lb. payload of meteorological instruments for upper atmosphere investigations. Also boosted by a short-duration solid propellant rocket, its motor was of the liquid propellant type, utilising red fuming nitric acid and aniline. In 1945 it established an American altitude record of 43½ miles. Fig. 21 shows the Bumper-Wac, a two-stage high altitude research vehicle in which the WAC Corporal was fired from an altered German V-2 used as a first stage. This combination in 1949 reached an altitude of 250 miles which, insofar as is known, remained the highest altitude attained by a man-made device until very recently.

The next in the series of J.P.L. missiles was the Corporal, originally designed as a fully guided research vehicle having considerable range and a very substantial payload for research instrumentation. Its flight

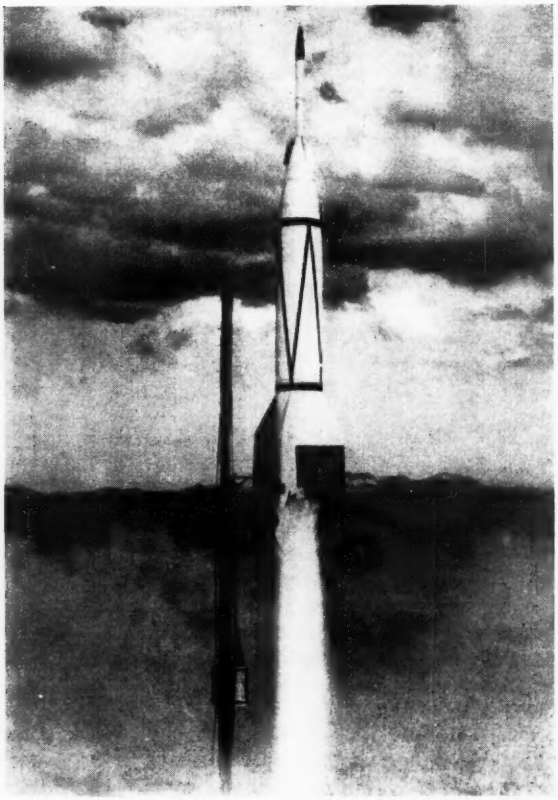

FIGURE 21. Bumper-WAC being launched on its 250 mile altitude flight.

FIGURE 22. Launching a tactical Corporal missile.

performance suggested that it could be developed into a tactical missile capable of carrying a nuclear warhead. The Laboratory was assigned the responsibility for this development, which culminated in early 1954 in the acceptance by the Army of the liquid propellant Corporal as the country's first long-range tactical supersonic guided missile. Fig. 22 shows the launching of a Corporal essentially identical to those with which overseas battalions of the United States Army are already equipped. Following completion of the Corporal programme and the transfer of responsibility to industrial firms for its quantity production, the Laboratory was assigned the job of developing a much improved ballistic missile system, the Sergeant, on which it is currently working. J.P.L. has also contributed significantly through its supporting researches to several other of the country's guided missiles.

Of all the supporting and basic researches which underlie this missile development programme, only those in one field, aerodynamics, can be mentioned within the scope of this lecture. The facilities here include a 12 in. supersonic tunnel reaching a Mach number of 4, a 20 in. tunnel attaining a Mach number of 5, shown with one side plate removed in Fig. 23, and a 20 in. hypersonic tunnel designed for the Mach number range from 4·5 to 8·5, which is currently under construction. A $\frac{3}{8}$th scale model of the water-cooled, adjustable nozzle and test section of the latter is currently under test as Leg 2 of the G.A.L.C.I.T. hypersonic facility, as was mentioned earlier, and will remain as a G.A.L.C.I.T. research tool when the tests are completed. The two supersonic tunnels have been used for hundreds of development type tests on many of the country's supersonic missiles, but have also been utilised in important unclassified basic researches on skin friction, boundary layer stability and transition, turbulence in supersonic flow, and so on. The Aerodynamics Division has also carried out theoretical and experimental studies of supersonic wing characteristics, missile stability and dynamics, real gas effects such as dissociation and ionisation which occur in hypersonic flows, and many other aspects of modern gas dynamics. Especially close and fruitful relations obtain between the Aerodynamics Division and the fluid mechanics staff of the G.A.L.C.I.T.

Dr. W. H. Pickering, the Laboratory's distinguished Director, has succinctly expressed the basic *raison d'etre* of the J.P.L. as follows:

> "The past two decades have seen the military strength of America become increasingly dependent upon the foresight and ingenuity of its scientists. Today the majority of the outstanding scientists of this country are contributing a part or all of their talents to the common defense. Developed for this

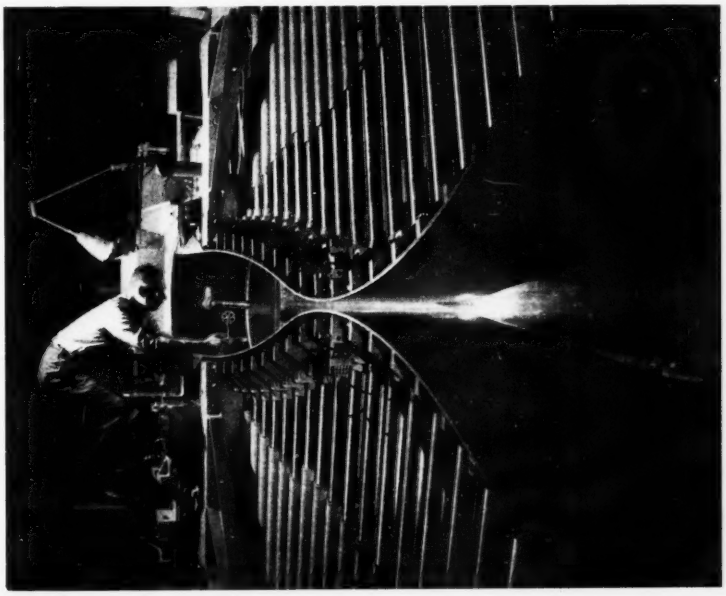

FIGURE 23. 20 in. supersonic wind tunnel nozzle and test section.

purpose, the Jet Propulsion Laboratory is an especially significant example of a new type of organization: the university-operated government-owned installation, which has proved to be the most satisfactory method for providing the civilian scientist with the opportunity of working on the defense team."

In addition to filling this need the J.P.L. has also made important contributions to the academic life of its parent institution.

10. Conclusion

After the first two-thirds of the manuscript of this lecture had been drafted I learned of Professor A. R. Collar's Fourth Barnwell Memorial Lecture: "A Specification for Engineering Education."* Professor Collar was kind enough to send me a copy of his lecture which I have read with tremendous interest and enthusiasm, the latter arising very naturally from my observation of the large number of points on which we seem to be in basic agreement. It occurred to me that a few comments stimulated by Professor Collar's paper might help to relate my remarks, based entirely on American experience to a British audience. Professor Collar has addressed himself to the entire field of aeronautical technological training, whereas I have limited myself to the small segment employing rather advanced scientific disciplines. In this area we are together in emphasising the importance of a broad curriculum including humanities and the basic physical and engineering sciences. There is, however, one rather interesting difference in our discussions which, I think, follows very directly from the difference in British and American life and traditions over the past century or so. Professor Collar, in effect, makes a plea for the respectability of engineering, and urges scientists to interest themselves in the "applied" problems. In the United States, with its fairly recent "frontier" way of life, the "practical" man who could do things with his hands has been viewed with respect if not reverence, while, until fairly recently, the long-haired intellectual has been considered somewhat ineffectual. The American institutions to which I have referred have, in effect, been trying for the past few decades to make the engineer not more respectable but more scientific. Professor Collar urges that this kind of advanced education be given in the universities rather than in special technological institutes. My remarks, I believe, apply equally well to American universities and to institutes of technology like M.I.T. and Cal. Tech. For during the past quarter century the atmosphere and curricula of the latter have become very similar to those which the student of science or engineering would experience at a university, where all the classical disciplines are represented. Thus it seems to me that the distinction which Professor Collar makes in this connection has largely disappeared in many American institutions.

Finally, a word of apology is perhaps in order in connection with my rather detailed account to a British audience of American practices for the support of academic research. I am convinced that the subject itself is of vital importance, and hope that the specific mechanisms I have reported, even though not directly applicable in Great Britain, may prove at least suggestive and perhaps helpful.

*Journal of the Royal Aeronautical Society, August 1957.

A vote of thanks to Dr. Millikan was proposed by Mr. P. G. Masefield, Hon.F.I.A.S., F.R.Ae.S., Vice-President of the Society, and was seconded by Dr. E. S. Moult, F.R.Ae.S., also a Vice-President of the Society.

Following the Lecture the Annual Dinner of the Council of the Society was held at 4 Hamilton Place, W.1, at which the following were present:—

H.R.H. The Prince of the Netherlands, Honorary Fellow 1957.

Mr. Charles Abell, O.B.E., F.R.Ae.S., British Silver Medallist 1957, Deputy Operations Director (Engineering), British Overseas Airways Corporation.

Dr. A. M. Ballantyne, T.D., B.Sc.(Eng.), Hon.F.C.A.I., A.F.I.A.S., F.R.Ae.S., Secretary, Royal Aeronautical Society. Air Commodore F. R. Banks, C.B., O.B.E., M.I.Mech.E., Hon.F.I.A.S., F.R.Ae.S., Member of Council; Director, Bristol Aeroplane Co. Ltd. Mr. A. J. Barrett, A.F.R.Ae.S., Head of Technical Department, Royal Aeronautical Society. Professor A. D. Baxter, M.Eng., M.I.Mech.E., F.R.Ae.S., Member of

Council; Professor of Aircraft Propulsion, College of Aeronautics. Lieutenant Colonel J. B. H. Bruinier, Air Attaché, Royal Netherlands Embassy. Major G. P. Bulman, C.B.E., B.Sc., F.R.Ae.S., Honorary Treasurer, Royal Aeronautical Society; Director of Construction of Research Facilities, Ministry of Supply.

Sir Sydney Camm, C.B.E., F.R.Ae.S., Member of Council; Director and Chief Designer, Hawker Aircraft Ltd. Air Commodore G. Carter, C.B.E., F.R.Ae.S., R.N.Z.A.F.(Retd.), Past President, New Zealand Division, Royal Aeronautical Society; Managing Director, Bristol Aeroplane Co. (New Zealand) Ltd. Mr. Thomas T. Carter, Civil Air Attaché, American Embassy. Mr. Charles H. Colvin, M.E., F.I.A.S., F.R.Ae.S., President, Colvin Laboratories Inc. Mr. J. R. Cownie, B.Sc.(Eng.), Grad.R.Ae.S., Member of Council; Handley Page Ltd. Lieutenant General Laurence C. Craigie, A.F.I.A.S., Vice-President, Institute of the Aeronautical Sciences; Director, G. M. Giannini and Co. Inc.

Mr. Handel Davies, M.Sc., A.F.I.A.S., F.R.Ae.S., Member of Council; Deputy Director General, Future Systems, Ministry of Supply. Dr. Hugh L. Dryden, Hon.F.I.A.S., Hon.F.R.Ae.S., Director, National Advisory Committee for Aeronautics.

Sir George Edwards, C.B.E., B.Sc., F.R.Ae.S., President, Royal Aeronautical Society; Managing Director, Vickers-Armstrongs (Aircraft) Ltd.

Sir William S. Farren, C.B., M.B.E., F.R.S., M.I.Mech.E., Hon.F.I.A.S., F.R.Ae.S., Member of Council; Technical Director, A. V. Roe and Co. Ltd.

Dr. G. W. H. Gardner, C.B., C.B.E., B.Sc., F.R.Ae.S., Member of Council; Director, Royal Aircraft Establishment. Mr. H. H. Gardner, B.Sc., F.R.Ae.S., Member of Council; Chief Engineer (Military) Vickers-Armstrongs (Aircraft) Ltd. Sir Harry M. Garner, K.B.E., C.B., M.A., F.R.Ae.S., Member of Council. Lieutenant Colonel C. C. Geertsema, Aide-de-Camp to H.R.H. The Prince of the Netherlands. Professor Dr. D. Goedhuis, Civil Air Attaché, Royal Netherlands Embassy. Mr. F. B. Greatrex, B.A., A.M.I.E.E., Society's Bronze Medallist, 1957; Chief Development Engineer, Installation Division, Rolls-Royce Ltd. Commander W. de Groot, Netherlands Air Arm. Mr. L. R. Grumman, Hon.F.I.A.S., Chairman, Grumman Aircraft Engineering Corporation.

Sir Arnold A. Hall, M.A., F.R.S., F.R.Ae.S., President-Elect, Royal Aeronautical Society; Technical Director, Hawker Siddeley Group. Monsieur A. H. Hasselman, Chargé d'Affairs a.i., Royal Netherlands Embassy.

Brigadier General F. B. James, U.S.A.F., Air Attaché, American Embassy. Mr. S. Paul Johnston, B.Sc., F.I.A.S., F.R.Ae.S., Director, Institute of the Aeronautical Sciences. Air Marshal Sir Owen Jones, K.B.E., C.B., A.F.C., B.A., D.I.C., M.I.Mech.E., F.R.Ae.S., Vice-President, Royal Aeronautical Society; Consultant.

Mr. B. P. Laight, M.Sc., A.M.I.Mech.E., F.R.Ae.S., Member of Council; Chief Designer (Aircraft), Blackburn and General Aircraft Ltd. Mr. R. L. Lickley, B.Sc., M.I.Mech.E., F.R.Ae.S., Member of Council; British Gold Medallist, 1957; Technical Director and Chief Engineer, Fairey Aviation Co. Ltd. Mr. H. C. Luttman, M.A., A.F.I.A.S., A.M.I.Mech.E., A.F.C.A.I., A.F.R.Ae.S., Secretary, Canadian Aeronautical Institute. Mr. Bernard I. Lynch, R. P. Alston Memorial Medallist, 1957; Chief Instructor, Martin-Baker Aircraft Co. Ltd.

Professer H. J. van der Maas, O.O.N., D.Sc.(Eng.), F.R.Ae.S., Professor of Aeronautics, Delft Technological University. Mr. E. J. Mann, F.R.S.A., A.I.Mech.E., A.R.Ae.S., Member of Council; The de Havilland Aeronautical Technical School. Mr. Roy E. Marquardt, A.F.I.A.S., Vice-President, Institute of the Aeronautical Sciences; President, Marquardt Aircraft Co. Mr. P. G. Masefield, M.A., Hon.F.I.A.S., F.R.Ae.S., Vice-President, Royal Aeronautical Society; Managing Director, Bristol Aircraft Ltd. Dr. Clark B. Millikan, Hon.F.I.A.S., F.R.Ae.S., Forty-Fifth Wilbur Wright Memorial Lecturer; Director, Guggenheim Aeronautical Laboratory. Mr. M. B. Morgan, M.A., F.R.Ae.S., Member of Council; Society's Silver Medallist, 1957; Deputy Director, Royal Aircraft Establishment. Dr. E. S. Moult, B.Sc., M.I.Mech.E., F.R.Ae.S., Vice-President, Royal Aeronautical Society; Director and Chief Engineer, The de Havilland Engine Co. Ltd.

Mr. F. M. Owner, C.B.E., M.Sc.(Tech.), M.I.Mech.E., F.R.Ae.S., Member of Council; Consultant.

Captain J. Laurence Pritchard, C.B.E., Hon.F.I.A.S., Hon.F.R.Ae.S., Formerly Secretary, Royal Aeronautical Society.

Mr. R. D. Richmond, M.I.A.S., Chief Engineer, Special Weapons, Canadair Ltd. Mr. N. E. Rowe, C.B.E., B.Sc., F.C.G.I., F.I.A.S, F.R.Ae.S., Past President, Royal Aeronautical Society; Technical Director, Blackburn and General Aircraft Ltd.

Mr. S. Scott Hall, C.B., M.Sc., D.I.C., F.C.G.I., F.I.A.S., F.R.Ae.S., Member of Council; Scientific Adviser, Air Ministry. The Rt. Hon. Lord Sempill, A.F.C., M.I.P.E., F.R.Ae.S., Consulting Engineer. Dr. Edward R. Sharp, F.I.A.S., Director, Lewis Flight Propulsion Laboratory, National Advisory Committee for Aeronautics. Mr. B. S. Shenstone, M.A.Sc., F.C.A.I., A.F.I.A.S., F.R.Ae.S., Member of Council; Chief Engineer, British European Airways Corporation. Mr. P. F. Sutherby, B.A., N. E. Rowe Medallist, 1957; Elliott Brothers (London) Ltd. Mr. Elmer A. Sperry Jr., F.I.A.S., Vice-President and Treasurer, Sperry Products Inc.

Mr. Caradoc Williams, Wakefield Gold Medallist, 1957; Assistant Director, Engineering Division, Radio Department, Royal Aircraft Establishment. Mr. L. A. Wingfield, M.C., D.F.C., A.R.Ae.S., Solicitor to the Royal Aeronautical Society. Dr. T. P. Wright, Hon.F.I.A.S., Hon.F.R.Ae.S., President, Cornell Aeronautical Laboratory.

Possible Flight Paths for Helicopters*

by

P. F. SUTHERBY, B.A.

(Formerly Bristol Aeroplane Co. Ltd., now with Elliott Bros. (London) Ltd.)

IT HAS BEEN normal in discussion of helicopter operations to assume that the aircraft will operate at low altitudes. In particular, the commercial operation of helicopters on "inter-city" routes is usually assumed to take place between altitudes of 1,000 and 2,000 ft. with the appeal of the view of the countryside adding to the attractions of this means of transport.

It is intended to show in this paper that there are considerable advantages to be gained from flying very much higher than these low altitudes, and in using flight paths very similar to those of conventional air liners.

NOTATION

C_T	thrust coefficient $\frac{T}{\pi R^2 \rho_0 \sigma V_T^2}$
P_{pr}	rotor profile power
R	rotor radius
s	solidity at $\frac{3}{4}$ radius
T	thrust on one rotor
V	forward speed of helicopter
V_T	blade tip speed
δ	profile drag coefficient of blades
μ	tip speed ratio
ρ_0	air density at I.S.A. sea level conditions
σ	relative density

Type of Aircraft

First, it is important to consider the type of aircraft which will be operating on these inter-city routes. It will be large; accommodation will be required for between forty and sixty persons and a crew of at least three. It will almost certainly be powered by some form of gas turbine and, it will also have a sufficiently large reserve of power to enable it to hover with one engine dead outside the ground cushion under all conditions of temperature and altitude likely to be met with at its termini. This last may sound a stringent condition to apply, but it is likely to be necessary to allow a large and heavily-laden helicopter to operate in safety from city centres. The damage caused by a 5,000 lb. helicopter crash-landing in a street might be quite small, but the devastation caused by a 50,000 lb. machine with some 5,000 lb. of fuel aboard would be very serious and it would be likely to do irreparable harm to helicopter operations, both by the repressive safety precautions which might be introduced as an immediate result, and by the effect on the morale of the travelling public.

The aircraft may be a simple helicopter, which is defined for this paper as a helicopter without wings although with any number of rotors; or it may have wings to assist in unloading the rotor in forward flight. It is possible that it may have propellers to assist with thrust in forward flight with the rotor either continuing to supply forward thrust, as well as lift, or auto-rotating as on the gyrodyne.

It is not proposed in this paper to consider the type of vertical take-off aircraft which is completely supported by wings in forward flight. That is, one in which some form of jet lift is provided in hovering flight, or one in which either the rotors or the complete aircraft is tilted through 90° to obtain the transition from hovering to forward flight and back again. This type of machine can be treated as a conventional aircraft once it is obtaining all its lift from its wings.

In cruising flight at low altitudes the type of inter-city helicopter mentioned previously, that is an aircraft capable of hovering with one engine dead, will have a large amount of surplus power and, since it is wasteful to run turbines at low power and at low altitude, it appears probable that for economy, some different form of flight path is preferable. It is now possible to consider the effects of the characteristics of this type of aircraft, and the gas turbines that power it, on the flight performance.

Optimum Conditions for a Helicopter

In the free turbine type of power unit, nearly constant power is delivered over a wide range of output speeds, a loss of only 5 per cent in power over a range of ± 20 per cent from the optimum r.p.m. is possible, and better figures might be obtained if this were required as a primary feature of the design. Also, the specific consumption of a turbine decreases both with increase of altitude and with increase of power. The first of these characteristics makes it possible to operate a rotor at, or near, its optimum speed and the second tends to make it economical to fly high with the engine running as hard as possible.

In the past, with piston-engine-powered helicopters, the cruising rating of the engine has determined the r.p.m. of the rotor, which has, as a result, invariably been less than the r.p.m. in hovering. This is an unsatisfactory state of affairs, since higher r.p.m. are preferable for forward flight; and designers have been forced to consider expedients such as variable ratio gear boxes with the pilot literally changing gear while changing from one flight state to another. Also with a

* The first paper to be awarded the N. E. Rowe Medal in the age group between 21 and 26 years. The paper was originally given to the Bristol Branch.

piston engine the specific fuel consumption is approximately constant with altitude, and increases considerably with increase of engine output above the comparatively low fraction of maximum power which is the weak mixture cruise rating.

To obtain an expression for the optimum r.p.m. of a helicopter powered with a free turbine, it is necessary to consider only the equation of profile power assuming the engine output to be constant. The equation for profile power is normally written

$$P_{pr} = \tfrac{3}{16}\pi R^2 \rho_0 \sigma s \delta V_T^3 (1 + 4{\cdot}6\mu^2)$$

for constant chord blades. In forward flight it appears necessary to increase this further by a factor $F\delta$ which depends on μ and on C_T/s and this gives some measure of the rise in drag due to the reversed flow region and the approach of blade tip stall. This factor $F\delta$ is normally expressed graphically since the mathematical expression for it is complex; and, since the expression is complex and does not lead to convenient differentiation, it is more practical to include δ, $(1+4{\cdot}6\,\mu^2)$ and $F\delta$ in a single approximation of the form

$$(a + b\mu + c\mu^2) + (a' + b'\mu + c'\mu^2)\frac{C_T}{s}$$

and we may now differentiate with respect to V_T to obtain $\dfrac{dP_{pr}}{dV_T}$ and the minimum profile power occurs when $\dfrac{dP_{pr}}{dV_T} = 0$.

The resulting equation is a quartic for V_T.

An approximate root of this is the expected operating tip speed of the aircraft and a more accurate root can then be derived in the normal manner, a single stage of the approximation process being sufficient for normal purposes. The result of solving this quartic is to show that an increase in speed, altitude or weight requires an increase in r.p.m. for the aircraft again to be operating at its optimum conditions.

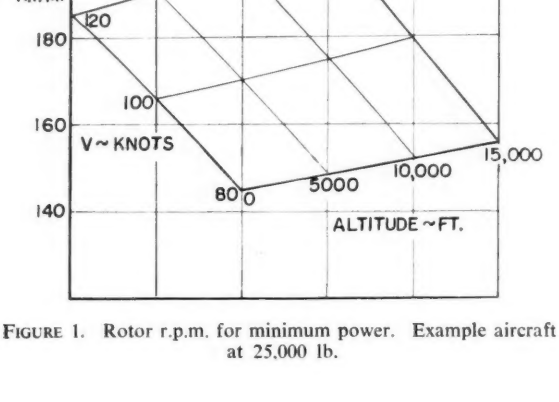

FIGURE 1. Rotor r.p.m. for minimum power. Example aircraft at 25,000 lb.

Example Helicopter

As a numerical example this can be applied to a helicopter based on considerations indicated in the opening paragraphs. The helicopter for these examples is slightly smaller than the fully developed model mentioned there, and is thus more representative of the first generation of civil helicopters which will be able to offer regular services as a commercial proposition. The machine considered is then, a twin-rotor helicopter with rotors approximately 64 ft. in diameter, with an all-up weight of 30,000 lb. and 10,000 lb. available for fuel and payload. The maximum seating over ranges up to about 100 miles would be for 40 passengers.

For this aircraft Fig. 1 shows the variation of optimum operating r.p.m. with speed and altitude at a given weight, and Fig. 2 the variation with speed and weight at a given altitude. It can be seen that the variation is from below 150 r.p.m. at low speeds, weights and altitude to 210 r.p.m. at 12,000 ft., 120 kts. (139 m.p.h.) and 30,000 lb. This is well within the range quoted previously for a turbine geared down to give optimum power at 180 r.p.m. The next stage is, using a range of 150 to 220 r.p.m., to obtain the best operating conditions for the helicopter.

Taking the case of the same helicopter and considering it to be equipped with four free-turbine engines delivering a maximum of 1,000 h.p. each at a specific consumption of 0·7 lb. fuel/h.p./hr. at I.S.A. sea level conditions, which is a reasonable value for this size of turbine, we may assume from this a variation in power and specific consumption with altitude which is normal for this type of engine and calculate the best cruising conditions.

First, however, having considered the choice of engines, it is appropriate to note that with this power loading, which is sufficient to give a three-engined vertical rate of climb at full all-up weight under all conditions to be met with in Europe, the four-engined vertical rate of climb at a minimum hovering r.p.m. of approximately 150 will be between 1,000 and 1,500 ft./min. if the transmission is stressed to take the full

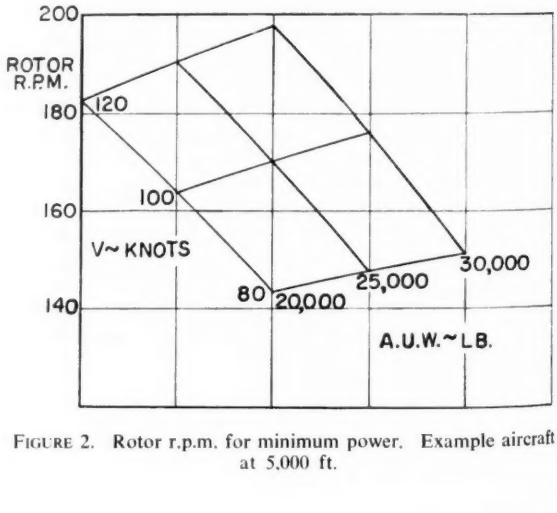

FIGURE 2. Rotor r.p.m. for minimum power. Example aircraft at 5,000 ft.

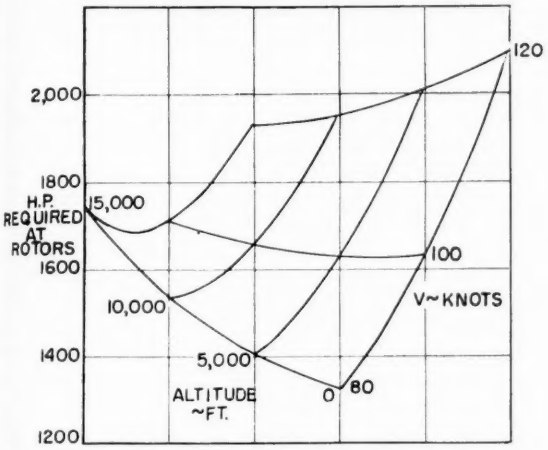

FIGURE 3. Power required in level forward flight. Example aircraft at 25,000 lb.

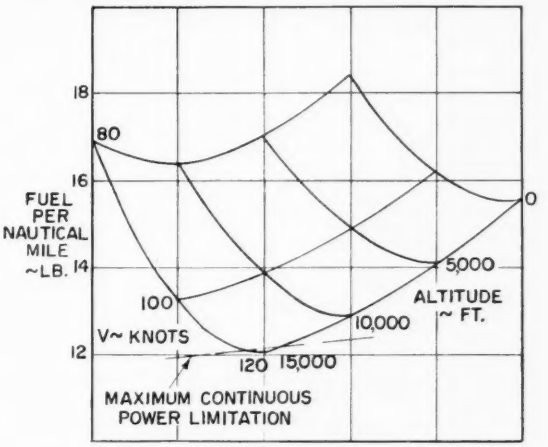

FIGURE 4. Cruise consumption. Example aircraft at 25,000 lb.

available power. This is far larger than it is convenient to use in airline operation and some of the surplus power could be used by running the rotor in hovering flight near its maximum r.p.m., in this case assumed at 220, and so maintaining a large safety factor in case of engine failure; for the kinetic energy stored in the rotor, together with the torque from the remaining engines will make it almost impossible to allow the rotors to slow down dangerously. In fact, the power setting for four engines at 220 r.p.m. is very near that for three engines at 150 r.p.m. and, indeed, if the aircraft could be hovered at 140 r.p.m. the only reaction required of the pilot would be the change of collective pitch.

An additional advantage of hovering at high r.p.m. in such a case is that the torque on the transmission is reduced at the time when it is absorbing the greatest amount of power, and this will have a favourable effect on the life of the components.

Returning to the forward flight case; the variation of power required with speed and altitude is plotted in Fig. 3 at 25,000 lb. This is plotted regardless of any low limit on the r.p.m. and it shows that, at 120 kts. (139 m.p.h.), minimum power height is nearly 15,000 ft.; at 100 kts. (115 m.p.h.) it is about 4,000 ft., and at lower speeds the power required is still decreasing at sea level. Using the engine performance, and graphs similar to Fig. 3 at a range of weights, it is now possible at each weight to plot consumption in lb. of fuel/mile against altitude and speed and Fig. 4 shows this done again for an all-up weight of 25,000 lb. It can be seen that the speed for minimum consumption varies little with altitude and is between 115 and 120 kts. (130 and 139 m.p.h.).

The dotted line shows the limit of maximum continuous power and it shows that, despite the large surplus of power at sea level hovering conditions, there is insufficient power available at altitude for the helicopter to be flown at its most economic height and speed.

This limitation due to lack of power at altitude is more severe at higher weights and in Fig. 5 the consumption at most economical speed is plotted against weight and altitude with the limiting line of engine power included. It can be seen as a general rule that for economy this aircraft should cruise at maximum continuous rating at about 120 kts. (139 m.p.h.) at the highest altitude that these conditions allow.

Cruising at Altitude

Now consider the effect of a simplified flight plan for an aircraft taking off at 30,000 lb. and flying stages of up to 200 miles. The plan consisting of climbing on one hour power at 100 kts. (115 m.p.h.) to 5,000, 10,000 or 15,000 ft. and flying the intermediate distance at 120 kts. (139 m.p.h.) without regard to engine limitations.

The results of this show that for a 50 nautical mile stage a height of 4,000 ft. gives the most economic overall cruise and this height increases to 8,000 ft. at 100 n.m. and 11,000 ft. at 200 n.m., the limit on the height being largely the rate of climb attainable at one hour power. The net saving on a long stage is between 15 per cent and 20 per cent of the fuel consumption over the same stage at sea level and no airline struggling to lower its costs is going to neglect this. Alternatively a smaller and cheaper aircraft may be designed to operate a given stage with a fixed payload.

This implies that helicopters of this type will be cruising as high as they can without causing discomfort to the passengers; that is between 5,000 and 8,000 ft.

With other types of helicopter the effect of cruising at altitude will be similar, with possibly an even more prounounced saving. If wings are used to unload the rotor, the savings in parasite drag and in fuel consumption of the engines remain, the induced power will be similar and there will be a saving on the profile power since the rotor will be operating at a lower incidence which implies a lower r.p.m. for its optimum conditions. If the helicopter is powered by tip jets on a system similar to the Percival pressure jet, the

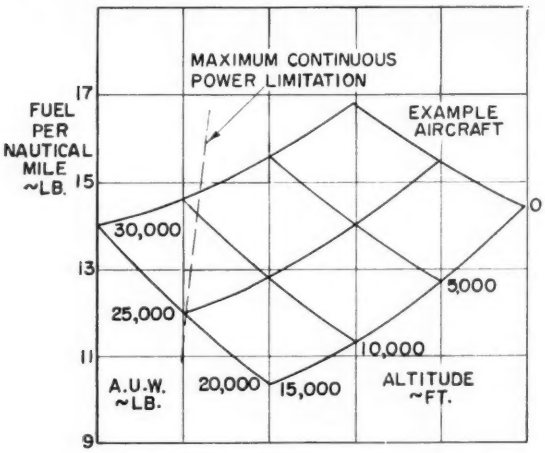

FIGURE 5. Cruise consumption at speed for maximum economy.

efficiency of the tip jets will be increased by the increase of rotor r.p.m. which goes with flight at altitude, thus giving a double gain, since the efficiency of the gas turbine units will also be improved. This type of helicopter is bound to have a fairly thick blade to act as an efficient duct for the hot gases and the saving in profile power due to the lower density at altitude will possibly be more noticeable than on conventional thinner bladed machines.

Effects of Higher Altitude Operation

It is now possible to look at some of the trends in design and operations which may be encouraged by higher altitude operations. Since the aircraft will be operating below its optimum altitude, there will be no great incentive to lower disc loadings and the present trend of increasing disc loading will probably continue.

A requirement for higher speed will encourage the reduction of parasite drag, although at altitude the saving will not be as great as at sea level and the weight penalty of fully retracting undercarriages and similar refinements may not always make them worthwhile.

Modern civil aircraft are frequently flown at speeds above their economical cruise speed in order to increase their work capacity. The penalty in fuel consumption for doing this is much less at altitude than at sea level. Time lost in climb is minimised if the aircraft is climbed at speed near its cruising speed, rather than at the speed for best climb; the greater part of this lost time might be regained by descending at a speed above that used in cruise.

Blade stalling will be minimised by the increase in r.p.m. but Mach number effects on the blade tips may cause the adoption of thinner blades or of blades tapering in thickness although of constant chord. The example helicopter cruising at 120 kts. (139 m.p.h.) at 10,000 ft. and at 25,000 lb. weight, for instance, has an advancing tip Mach number of nearly 0·8, although this is at a tip speed ratio of just under 0·3. One of the effects of wings unloading the rotor will be to lower the r.p.m. for optimum operation which will have the effect of reducing this tip Mach number.

Apart from this high Mach number the rotor will not be operating in conditions far removed from those reached in helicopters at present flying; the high r.p.m. keeping the tip speed ratio below 0·3 and the blade incidence at high r.p.m. being lower than the value on several helicopters at present in service.

At altitude the effects of total engine failure will be minimised since the length of the glide path will enable the pilot to choose a suitable landing site.

Conclusions

It would be rash, on the basis of performance estimations alone, to predict with confidence the future lines of development of commercial passenger-carrying helicopters; but it does seem to be indicated by the calculations that have gone into this paper that there will be two types developed. The first will be for short stages, perhaps under 120 miles; it will be a simple helicopter cruising at heights below about 6,000 ft. and may become the equivalent of the "semi-fast" train, serving stations intermediate between the major termini and areas where short journeys only are normally required.

The second type will be for longer stages; it is likely to have some form of fixed lifting surface and it will normally fly stages of 100 to 300 miles. This type will need to cruise at a considerable height for economy and it is possible that it will be found better to pressurise it and to fly at between 12,000 and 15,000 ft. or even higher. This is a very far cry from the simple aircraft cruising at ground level but if, taken all round, it proves a more economic proposition it will certainly be developed and introduced into service.

These proposed helicopters may well be found less attractive when weight and vibration factors are taken into consideration, but the propositions that there is a considerable fuel saving if a gas turbine helicopter is flown at high altitudes, and that these altitudes are practical if the full range of possible operating rotor r.p.m. is used, have been demonstrated. The influence these facts have on design will depend largely on other developments but, if performance becomes predominant, the aspect of commercial helicopter operations may be considerably changed.

Fins*

by

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(Folland Aircraft Ltd.)

JUDGING by the number of present-day aircraft which have suffered changes of fin shape, it is clear that there is still some difficulty in estimating the size and shape of fin required on a new project. In this paper some of the principles on which fin design is based will be explained, and some of the difficulties involved described.

1. Directional Stability

It is necessary to have some sort of fin to provide weathercock, or directional, stability. This is illustrated in Fig. 1. This shows the balance of yawing moments, due to sideslipping. In general, the side force acting on the fuselage, represented by the black arrow, has its c.p. ahead of the c.g. of the aircraft, and hence it produces a destabilising moment about the c.g. Sufficient fin area must be provided for the yawing moment due to the fin side force, represented by the white arrow, to at least equal the destabilising fuselage moment. Otherwise, when disturbed laterally due to, say, a gust, the aeroplane will tend to swing still further out of wind, making it difficult to fly accurately. The minimum permissible fin area can, in fact, be fixed simply by this requirement for weathercock stability.

To find out how much larger than this the fin must be, the lateral response characteristics of the aircraft must be considered.

Figure 2 shows a typical time history of aircraft response in angle of yaw, following a twitch of the rudder. It will be seen that the motion is made up of three modes, shown by the dotted lines. As far as fin design is concerned, the most important mode is the oscillatory one. This lateral oscillation is the most difficult mode for the pilot to control and it must, therefore, be well damped if the aircraft is to have good flying qualities.

1.1 CHOICE OF FIN AREA

We shall now see how the damping of the lateral oscillation depends on the fin area.

To measure the damping of an oscillation a parameter called logarithmic decrement, or for short, log. dec. is used. Log. dec. is the natural log. of the ratio of heights of successive peaks of the oscillation, as illustrated in the top right hand drawing of Fig. 3. The higher the damping, the bigger the log. dec.

The middle graph shows how a change in fin area affects the log. dec. This graph, and the others on this figure, are actually drawn for the Gnat flying at $M=0{\cdot}9$ at sea level, and in varying the fin area it has been assumed that the fin shape had not been changed. Although, naturally, the numerical values will be different for other aircraft, the general trends shown are typical.

It will be seen that the log. dec. increases towards an exceedingly high value as the fin tends towards 50 per cent of the basic fin area, that is, 50 per cent of the actual fin area as it is on the present Gnat. Fin areas of less than 50 per cent of the basic need not be considered, because if the fin does become as small as that it will not be able to maintain weathercock stability.

From the log. dec. graph, then, it is seen that the actual fin area (of 100 per cent) is larger than that for the highest log. dec. One reason for this is shown on the lower graph (Fig. 3). This shows how the maximum sideslip angle obtained following a suddenly applied yawing moment, due to, say, application of rudder, varies with fin area. The sideslip angles are plotted relative to a value of 1° for the 100 per cent fin, the same yawing moment being applied throughout. As can be seen, for fin areas of less than about 75 per cent, the sideslip angles attained become much too large for accurate flight.

Thus log. dec., by itself, does not provide a good criterion for fin design. This is because, although the log. dec. increases as the fin area decreases, as can be seen on the top graph, the period of the oscillation increases even more. Hence the total time taken for the oscillation to die away increases. As, theoretically, the oscillation goes on for ever, getting smaller and smaller, the time it takes to die away completely, strictly speaking, cannot be defined, and so to describe its rate of decay the parameter $T_{1/2}$ is used, the time to half amplitude. This is defined from the envelope of the

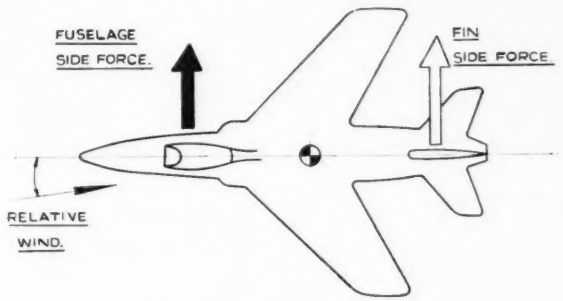

FIGURE 1. Weathercock stability.

* The runner-up paper for the 1957 N. E. Rowe Medal Competition in the 21 to 26 years of age group.

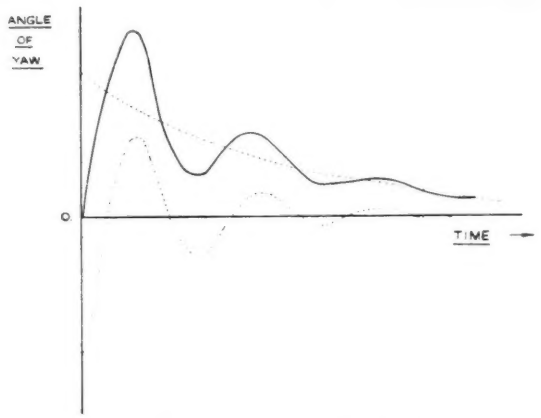

FIGURE 2. Lateral response characteristics.

oscillation, as shown in the top right hand drawing of Fig. 3.

Time to half amplitude is an important parameter in weapon aiming as it is proportional to the length of time in which the target is out of the fighter's sights, following a disturbance. Hence it is desirable to have the time to half amplitude short and, from the top dotted graph, it is seen that this can be done by increasing the fin area.

It is considerations of response and stability of this sort, together with requirements for spin recovery, and asymmetric flight, that, in the past, have governed the choice of fin area.

2. Inertial Cross-Coupling in Roll

Response calculations of this sort are almost always worked out on the assumption that the disturbance of the aircraft from its equilibrium position is small. Now by a "small disturbance" in, say, angle of bank, is meant a change in bank angle of less than 15° or so. Obviously, when the aircraft is rolling, this limit is going to be greatly exceeded. Nevertheless, in the past, fins designed on the basis of small disturbances have generally been satisfactory in rolling flight. However, it has recently become apparent that present design trends are likely to cause difficulties when rolling due to what is usually called inertial cross coupling in roll. This will now be discussed, and its effect on fin design.

Figure 4 illustrates the yawing moments due to its own mass, acting on a rolling aeroplane. The aeroplane is supposed to be yawed slightly out of wind and is supposed to be rolling steadily about an axis parallel to the relative wind, with no pitching motion. To make it easier to explain, the actual distributed mass of the aeroplane has been replaced by concentrated masses along its principal axes, at the appropriate radii of gyration.

The black arrows represent the centrifugal forces acting on the fuselage masses. They act in such a way as to produce a moment which tends to swing the aeroplane still further out of wind, in other words, they are destabilising. This moment is opposed by the moments

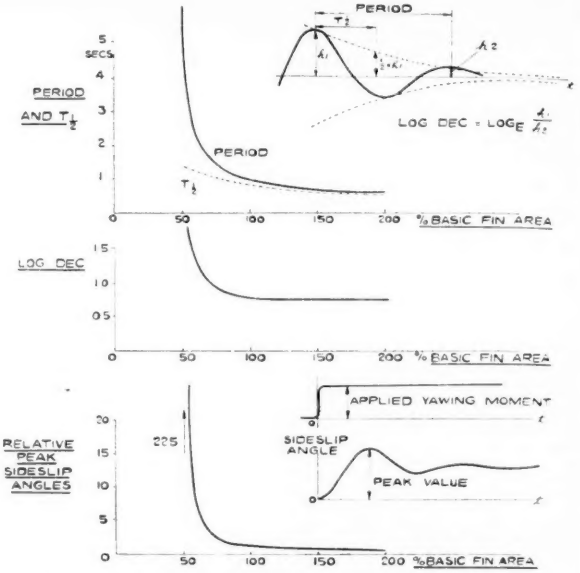

FIGURE 3. Effect of fin area on lateral stability and response.

due to the centrifugal forces acting on the wing masses, shown by the white arrows, but on almost all aircraft the destabilising moment is the more powerful.

Now this destabilising moment arises due to the centrifugal forces acting on the aircraft distributed mass and, for a given yaw angle, these centrifugal forces increase as the square of the rate of roll. Hence, if the aeroplane rolls at a sufficiently high rate the destabilising inertia moments will exceed the stabilising moment of the fin. If this happens, the aircraft will no longer have weathercock stability, and serious consequences may follow; at the very least the aircraft will be difficult to control.

Up to the present, this has not been of much importance because aircraft have tended to have fairly high inertia in a spanwise direction compared to their lengthwise inertia, and so the rate of roll at which weathercock stability is lost, the critical rate of roll, has

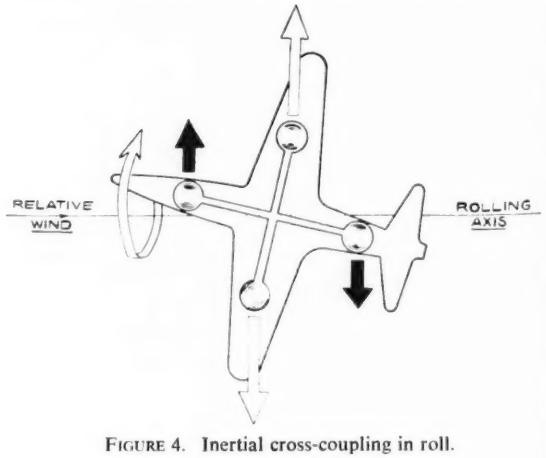

FIGURE 4. Inertial cross-coupling in roll.

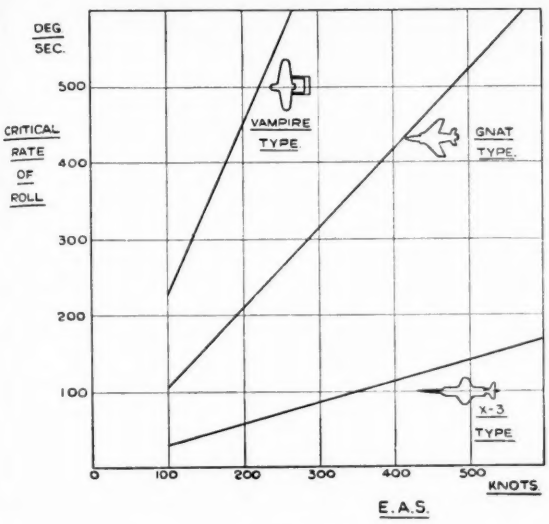

FIGURE 5. The critical rate of roll.

been much higher than anything likely to be obtained in flight. But, the present trend of aircraft design is to increase the fuselage inertia relative to the wing inertia, thus reducing the critical rate of roll. This is illustrated in Fig. 5.

Figure 5 shows the critical rate of roll plotted against E.A.S. for three types of aircraft. By making some simplifications, the graphs become straight lines. Actually they are not but, for the purpose of demonstrating general trends, it is sufficiently accurate to assume that they are.

For a typical subsonic straight-wing fighter, the critical rate of roll is much higher than anything likely to be obtained in flight. For a typical current swept-wing fighter, difficulty is only likely to be encountered at low E.A.S. where structural failure is unlikely.

However, for aircraft like the Douglas X-3, designed for $M=2$, the critical rate of roll is sufficiently low for this to be a very real problem. In fact, the position is rather worse than described, because, when rolling, the centrifugal forces acting on the aircraft's mass tend to produce instability in pitch as well as yaw and furthermore, the rolling aircraft tends to act as a gyroscope and precess, so that yawing moments induce pitching and vice versa. Thus the pilot will be faced with difficulties of control both longitudinally and laterally. To complete this tale of woe, the theoretical analysis of the subject is very difficult, and the equations of motion can only be solved on a digital or analogue computer.

To sum up, it does seem that to avoid inertial cross coupling in roll on advanced aircraft, we shall have to use a fin so large that the critical rate of roll is raised to at least 200°/sec. Because of this, I think that whatever the *shape* of fins to come may be, their size is going to increase.

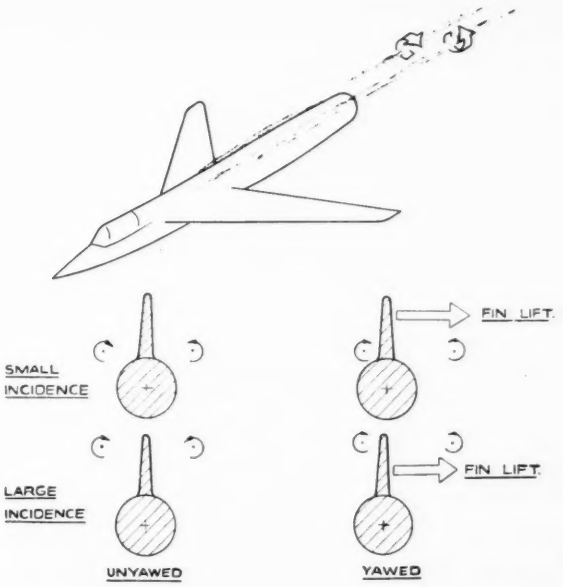

FIGURE 6. Fuselage-fin vortex interference.

3. Aerodynamic Aspects

So far, fin design as it is affected by the dynamics of the aeroplane has been discussed, first for gentle manoeuvres, then in rolling flight. Some of the purely aerodynamic aspects of fin design will now be discussed.

Fin aerodynamics is complicated by the interference effects of the body, tail and wings. Many of these interference effects are well known and understood; for example, it is common knowledge that a tailplane set near the base of the fin acts as an endplate, suppressing spillage of air round the base of the fin, and increasing its effectiveness. If the fuselage cross section is large near the fin it, too, acts as an endplate, still further increasing the fin effectiveness.

These interference effects have been studied in some detail for subsonic aircraft and design data on them is readily available, so little time will be spent discussing them. At transonic and supersonic speeds the interference effects become more complicated. There is an important interference on the fin from the fuselage; this effect is less well known and is worth describing in detail.

What happens is that shock-induced separations induce vortices along the fuselage as shown in Fig. 6. These vortices roll up to form two strong vortices which separate from the fuselage before they pass the fin. The effect of these vortices on the fin effectiveness is illustrated in the small diagrams.

These represent a cross section through the fin and fuselage looking forward. The fuselage vortices are represented by the curly arrows. These vortices trail off the fuselage roughly parallel to the relative wind, so that when the aircraft is unyawed they pass the fin at equal distances on either side. The right-hand diagrams

show what happens when the aircraft yaws. Here the aircraft is supposed to be yawed nose-to-starboard. Since both the fuselage vortices trail off roughly parallel to the relative wind, they both move to starboard relative to the fin. This means that the starboard vortex passes the fin some way out to starboard where it has little effect, whereas the port fuselage vortex moves closer to the fin.

At low incidence, the port vortex passes the fin close to its base. Now since the fin is lifting to starboard, air tends to spill round its base, from the port (high pressure) side to the starboard (low pressure) side. It is seen that the fuselage vortex is rotating in such a way as to oppose this spillage. So, by reducing this spillage, the fuselage vortex acts in the same way that an endplate would, and it actually increases the fin effectiveness.

Unfortunately, at high incidence, exactly the reverse occurs. Here the fuselage vortex passes the fin near the tip. Once again air is trying to spill round the tip of the fin from port to starboard, but now the direction of rotation of the fuselage vortex is in the same sense as that of the spillage. So at high incidence it actually encourages the air to spill round the tip, thus causing a loss of lifting effectiveness near the tip. This loss of lift may be so severe as to result in weathercock stability being lost.

This particular interference has a serious effect on the rolling pull-out manoeuvre. If a rolling pull-out is carried out at a sufficiently high C_L for this loss of fin effectiveness to occur, the aircraft may develop inertial cross-coupling troubles at rates of roll which would have been quite safe with the fin effectiveness appropriate to lower C_L's. One method that has been suggested of avoiding this interference is to dispose a good part of the fin area underneath the fuselage. This would, of course, introduce some ground clearance problems, and I think we shall just have to accept this interference, keeping the fin on top of the fuselage and increasing its area, if necessary.

4. Fin Shape

So far the effect of fin shape, as opposed to fin area, has not been discussed. The choice of fin shape is too complex a matter to be decided on purely aerodynamic considerations, and aeroelastic effects must be allowed for. These aeroelastic effects depend largely on the detail design of the aircraft, for example, the stiffness of the rudder circuit, and it is not possible to generalise about them. However, it is worth pointing out that the high lifting effectiveness of a high aspect ratio fin will often be largely cancelled out by its large aeroelastic losses and, for operation at high Mach numbers at moderate altitude, there may not be much to choose between one shape fin and another.

5. Conclusions

As will be appreciated, only a few of the many aspects of fin design have been covered. Topics such as fin requirements for spinning, for asymmetric flight, auto-stabilisers, and the structural aspects of fin design have had to be omitted, and various other topics mentioned only in passing.

The topics that have been discussed have been chosen on the basis of their interest and of their importance in the design of present-day high-performance aircraft.

In conclusion a few words should be said about the relation of fin design to the overall design of the aircraft.

Fin design is, of course, only one aspect of the general problem of stability and control. The early pioneers, like the Wright brothers, had to solve problems both of stability and control, and of power, before they could succeed. Since then progress in aircraft design has been governed by the power available.

Now the situation is changing. Nowadays, we have "enough power to fly a barn door"—what we lack is the knowledge of how to make it stable.

TECHNICAL NOTES

The Design and Operation of a Hydraulic Systems Functional Test Rig

by

J. M. LEWENDON, A.F.R.Ae.S.

THIS NOTE describes the design and operation of the rig used to test and develop the Canadair CP 107 "Argus" hydraulic systems. The Argus is a maritime reconnaissance version of the Bristol Britannia, redesigned and built in Canada for the R.C.A.F. by Canadair Ltd., Montreal.

INTRODUCTION

It is common practice on both sides of the Atlantic to test as thoroughly as possible before flight the various systems of a new aircraft. This is usually accomplished by the construction of space frames on which the systems are assembled and subjected to simulated flight conditions.

It was decided during the early stages of the design of the Canadair Argus that the deviations from the original Britannia hydraulic systems were great enough to warrant a full scale hydraulic systems test rig, in as compact a form as possible, which would give the desired test conditions and results.

DESCRIPTION OF HYDRAULIC SYSTEMS

The Canadair design team have extensively modified the original Britannia hydraulic systems to meet the more arduous demands imposed upon a military aircraft. All the major services could now be operated by either of two completely independent systems. The Main system is powered by two 8·5 U.S.G.P.M. constant displacement pumps mounted one on each inboard engine Sundstrand unit. These pumps operate the undercarriage, nosewheel steering, bomb bay doors, wheel brakes, and control surface locks. (Used for locking the free-floating control surfaces when the aircraft is parked.) The Emergency system, powered by a similar pump driven by a 200 V. 400 c.p.s. 3-phase motor operates the undercarriage, bomb bay doors, and wheel brakes. Control of both systems is divided between the first pilot and flight engineer.

DESIGN OF TEST RIG

The purpose of the test rig was four-fold:—

(*a*) To ensure that the 100 or so hydraulic components which had all been tested and approved as detail units, functioned satisfactorily when assembled together as complete aircraft systems.

(*b*) To check that during the operation of the systems no undesirable pressure peaks, back pressures, temperature increases, over-stressing, or air locks would occur.

(*c*) To record that the times of operation of the services, when working against representative loads, were within the specified limits.

(*d*) To establish data which could be used to predict performance on the aircraft, and which would form a basis of comparison for future tests which would be undertaken during the aircraft flight test programme.

In projecting the initial layout of the test rig the following major factors were considered:—

(*a*) All the aircraft components were to be mounted in their correct relative positions and attitudes.

(*b*) Various simulated air loads, and landing and taxying conditions were to be applied to the undercarriage, bomb bay doors and steering systems.

(*c*) Sufficient instrumentation was to be installed to allow a comprehensive survey of operating times, pressures, stresses, and fluid temperatures to be made.

(*d*) The rig was to be made portable in sections for transportation and installation in an environmental chamber for low temperature tests if required.

The major problem which had to be overcome in the initial design stage was the compressing of the layout of the hydraulic systems into a compact area without interfering to any great extent with the relative positions of the components. As located in the aircraft the systems occupied an area of 90 ft. by 80 ft., an envelope which would have made unreasonable demands upon the available floor space.

Upon examination it was observed that the disposition of the components in the aircraft formed a definite pattern. Groups of components in various equipment and undercarriage bays were separated by long runs of pipes. It was decided that these groups would be compressed and mounted on a sheet metal structure 45 ft. long and 5 ft. high, the Main system one side and the Emergency the other. The correct relative position of components within each group was strictly maintained, the only variation being that the number and degree of pipe bends between groups of components was not always representative of the aircraft. This was considered a justifiable deviation, due to the great saving in floor space which resulted (*see* Fig. 1). At one end of the wall a control panel incorporated the pilots and flight engineers controls, along with the instrumentation controls (*see* Fig. 2).

When considering the undercarriages, it was decided to have dummy nose and starboard main undercarriage legs mounted with all relevant hydraulics in frames which would incorporate a system of cables and weights to apply air loads to the legs. Provision for "*g*" loading was catered for by the addition of lead inserts in the dummy legs. The port main undercarriage jacks were mounted on the wall, and were synchronised hydraulically with the starboard main jacks.

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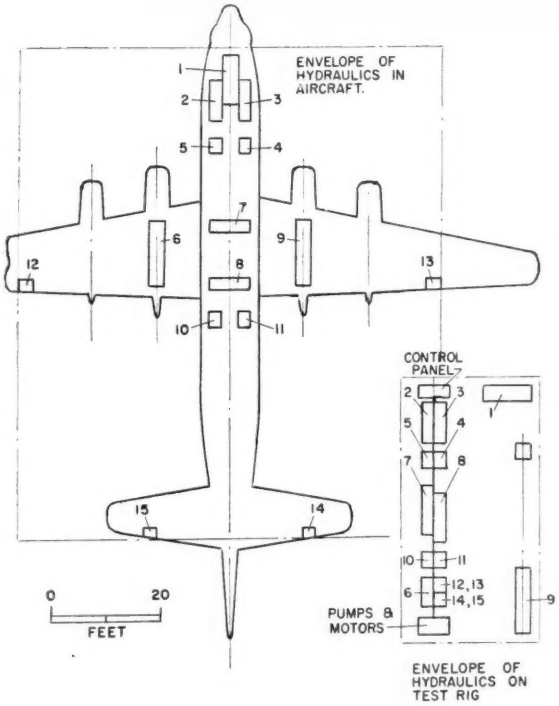

FIGURE 1. Disposition of hydraulics in the aircraft and on the test rig.

The bomb bay door jacks were disposed each side of the wall, mounted in yokes which also contained the jacks used to apply the air loads. These jacks were pressurised from accumulators, the geometry of the yokes determining the rate of application (*see* Fig. 3).

As no actual nose undercarriage leg was available at this early stage it was felt that the advantages of mounting the steering jack on the dummy leg were outweighed by the difficulties of applying operating loads with the jack in this position. The steering valve, and steering jack, together with a representative valve input and follow-up control system were therefore mounted in a separate frame close to that of the nose undercarriage. Loading of the steering was hydraulic, through the medium of a slave jack, and the loads could be varied to reproduce all runway cases.

The eight wheel brake units were simulated by eight small cylinders with floating pistons, the swept volume of one cylinder being equal to the maximum fluid demand for one wheel brake. Air pressure at the back of the pistons provided the opposing load from the brake release springs, and was a means of returning the floating pistons upon release of brake pressure.

The main system pumps were mounted on layshafts and belt-driven from two 15 h.p., 550 V., 60 c.p.s., 3-phase motors, this drive assembly being mounted at the opposite end of the wall to the control panel. The remote starter buttons were on the control panel, with an emergency stop button at the drive end of the wall. Both motors and starting equipment were flame-proof.

As it was anticipated that during prolonged testing of the system higher fluid temperatures than could normally be expected would be encountered, a heat exchanger was included in the Main system L.P. return line to the reservoir. This was in the form of a coil of pipe immersed in a tank of water with circulating flow. For normal system operation the coil could be by-passed thereby eliminating the unrepresentative additional back pressure.

The Argus being a large aircraft, the volume of fluid displaced during operation of the undercarriage circuit is considerable. Therefore, in addition to a handpump, a $\frac{1}{4}$ U.S.G.P.M. constant displacement pump driven by a 28 V. d.c. motor was tapped into the systems via the ground test connections. This later proved invaluable

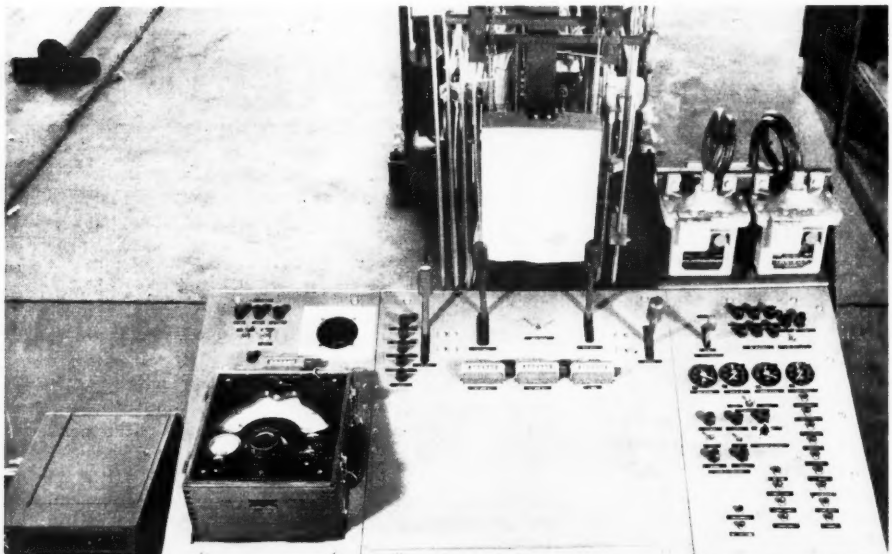

FIGURE 2. Test rig control panel. (Top right are the pump motor starter buttons, bottom left the oscillograph, and left centre the slide wire potentiometer.)

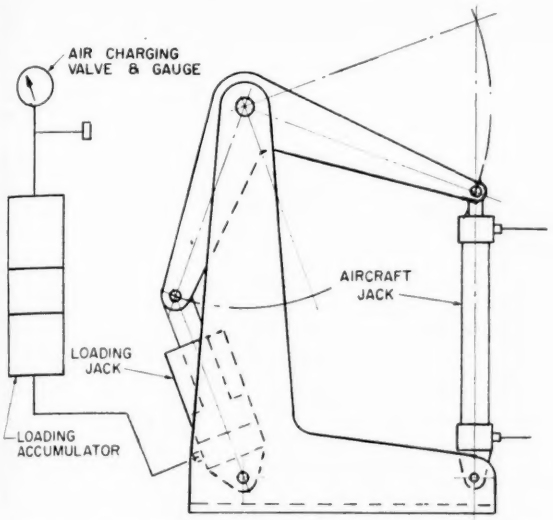

FIGURE 3. Bomb bay door jacks loading system. (It can be seen that the applied loading changes sense during jack extension and closure.)

for inching the services at a slow speed during observation of mechanical linkages and adjustment of micro-switches. Recourse to the handpump was necessary only for pressure testing the systems.

MANUFACTURE AND ASSEMBLY OF TEST RIG

The basic wall was manufactured in two sections, each capable of being lifted when loaded with all hydraulic equipment. The control panel and pump motor units were bolted at either end of the wall. The self-contained undercarriage and steering units were positioned and, together with the wall, grouted to the floor. The gaps between the wall and undercarriage units were bridged with channels of Dexion to carry the pipe lines and electrical wiring.

Several shop air and 110 V. power outlets were provided on the rigs at convenient points. In addition to overhead lighting, three mobile 500 W. flood lights on tripods were available.

At the earliest possible date orders were placed for the supply of a complete set of hydraulic components, to be delivered well in advance of the first production batch, as the aim was to complete the test programme before the first flight of the first aircraft. As these items were received they were subjected to the routine acceptance tests before installation on the rig. All components had completed the relevant qualification tests as detail assemblies, and were accepted as proven individual units.

During piping of the test rig the aircraft production drawings were used, as the rig layout was so often identical to that of the aircraft. This served as an additional check on the drawings, and allowed several assembly snags to be cleared before being encountered on the first aircraft.

INSTRUMENTATION

Apart from several direct reading pressure gauges the instrumentation was covered by two major pieces of equipment, an 18-channel oscillograph, and a slide wire potentiometer.

Pressures were measured by unbonded strain gauge transducers, the pressure changes being recorded in the oscillograph. The transducers could be coupled into any of the sixty pressure tappings arranged at critical points in the systems. The types of transducers available covered the following pressure ranges:—

0— 50 p.s.i.
0—1000 p.s.i.
0—5000 p.s.i.

Various links in the undercarriage mechanisms and jacks were instrumented with Baldwin SR4 strain gauges, the signals boosted by an amplifier again being fed into the oscillograph. Position potentiometers coupled to the jacks gave a trace on the oscillograph film from which positions and velocities could be obtained.

Oscillograph records could be taken on 7 in. wide paper, at speeds varying between 0·5 and 115 in./sec. Time intervals of 0·1 sec., and in some cases 0·01 secs., were automatically printed on the paper. The exact commencement of a selection could be printed as a blip in one of the channels. The oscillograph magazine held 120 ft. of paper, enough for 10 seconds continuous recording at maximum paper speed. The commencement of a recording could be controlled either manually, or triggered automatically by the start of the selection being recorded.

The slide wire potentiometer used to measure temperatures was coupled to a rotary selector switch which could select any one of twenty critical points in the systems. Temperature measurement range was from $-65°$F. to $+250°$F. As the potentiometer drew no current at balance, the length of lead between the instrument and the thermocouple did not have to be taken into consideration.

TEST PROGRAMME

The test programme was split into several sections as follows:—

(*a*) *System Capacity*

Using the $\frac{1}{4}$ U.S.G.P.M. pump the systems were operated one service at a time, simultaneously bleeding the jacks at the extremities of the services. The reservoirs were initially filled and subsequently topped up with measured quantities of fluid which had been filtered to 10 microns. When the reservoir levels consistently returned to the same mark after the operation of all services it was considered that the systems were filled and free from air. The fluid volume which had been introduced was then taken as the systems capacity, to be used as a reference for the aircraft systems.

(*b*) *Proof Pressure Test*

The complete h.p. circuits of both systems were subjected to a proof pressure of 1·5 working pressure (*i.e.* 4,500 p.s.i.) applied for 5 mins. Several relief valves which normally open before this pressure is reached were blanked off for this test. A similar test was performed on the L.P. circuits at a reduced pressure.

It was noticed while applying the pressure with the handpump that the systems tended to "stretch" for two or three minutes before stabilising. Careful examination after release of pressure showed that no permanent set had occurred. After a repeat pressure application had produced the same stretch it was attributed to the natural elasticity of a large system. (The combined fluid capacity of both systems is approximately 22 Imp. gallons.)

(*c*) *Functional Test*

Both main and emergency systems were operated with slowly increasing rates of pump delivery, but with no air loadings applied to any of the services. The systems were closely examined for any signs of malfunction, noisy operation, instability, or interaction between various circuits. It was during this phase of the testing that the majority of the usual phenomena which occur in any new hydraulic system, and which are unlikely to be discovered during the design stage, came to light. Individual development work was undertaken, and modifications were incorporated to make the systems function in a satisfactory manner. Using the oscillograph, a complete pressure survey of all jacks and pipe lines was then made. The free-condition operating times of the various services were established. Back-pressure checks were carried out, special attention being given to any position where back pressure could possibly cause malfunctioning of a service. An initial temperature survey was also undertaken at this stage.

The system high and low pressure filters were examined, and replaced. The contaminated elements were subjected to microscopic examination to ascertain the composition of the trapped particles.

(*d*) *Wheel Brake Systems Test*

After examining the brake circuits generally from a functional aspect, the oscillograph was used to ensure that the following conditions were being met:—

1. That the pressure distribution at the four brakes on each undercarriage bogie was the same at all times.
2. That the time required to build up and release full brake pressure was within acceptable limits.
3. That no excessive or lengthy brake pressure fluctuation occurred while changing from Main to Emergency systems with brakes applied.
4. That operation of other services, particularly the nosewheel steering, did not cause sufficient back-pressure to interfere in any way with the release of the brakes.

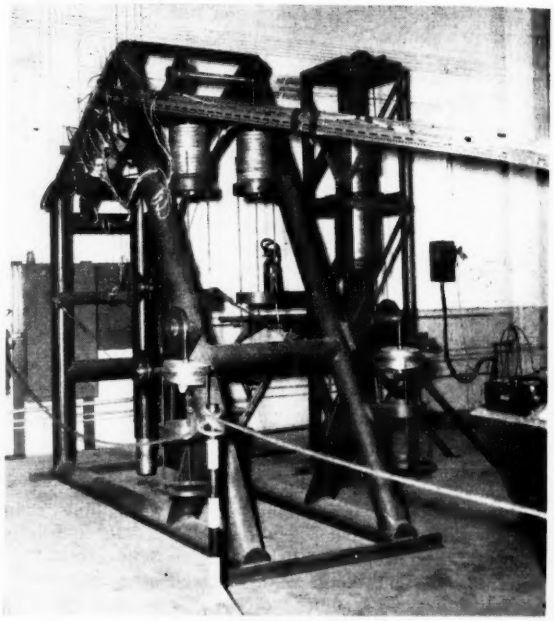

FIGURE 4. Nose undercarriage rig. (The weights are used to simulate the applied air loads.)

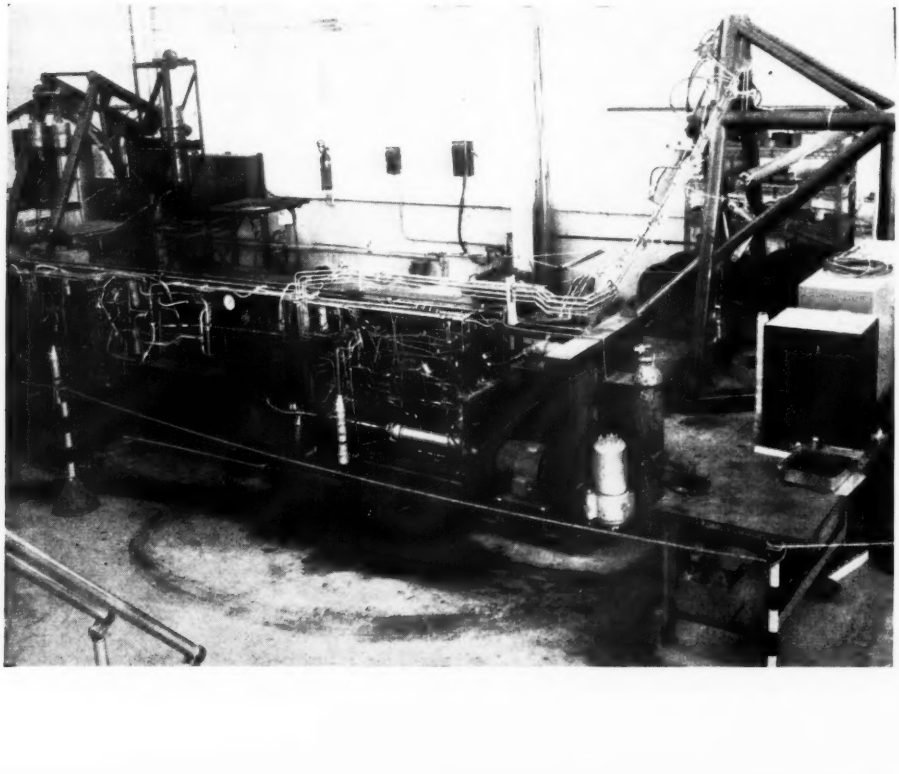

FIGURE 5. Starboard main undercarriage rig with applied loads. (The hydraulically-loaded port undercarriage jack can be seen on the wall to the right of the bomb bay door jack loading frame. Also visible are the heat exchanger tank and the motor driving one of the main system pumps.)

The number of complete brake operations stored in the Main and Emergency system brake accumulators, and the duration of full brake pressure from either system accumulator with the parking brake applied, were also determined.

(*e*) *Functioning With Applied Air Loads*

At this stage the landing gear and bomb bay door jacks were subjected to loads corresponding to various combinations of "*g*" and air-speed (*see* Figs. 4 and 5). Representative taxying and drift landing loads were applied to the steering jack. The oscillograph was again used to record pressures, stresses and velocities in the services during operation against these loads (*see* Fig. 6). The results formed the basis of the data to be used as a reference during future flight tests. A complete thermal survey was undertaken to establish the system's stabilising temperature, and the extent of any local hot spots, such as the pump delivery ports.

During this phase the 28 V. d.c. selector control system was operated at slowly reduced voltages, in order to find the minimum voltage at which the systems would function reliably. The effects of partial failures of the systems, such as the loss of one of the two pumps supplying the Main system were also determined.

A series of "interrupted operations" was carried out. This entailed reversing a selection in the undercarriage and bomb bay door circuits before it was completed in the normal manner (*i.e.* the undercarriage was selected "up", and at a pre-determined jack position the selection reverted to "down"). This was repeated at increments of jack stroke, going both from "down" to "up" and "up" to "down." Pressures and stresses measured during this test proved greater than those encountered during a normal selection, but were accepted with a reduced strength factor as these were considered emergency cases.

(*f*) *Low Fluid Level Test*

The functioning of the systems when operating at a reduced reservoir fluid level was observed. For this case it was assumed that the largest of the system accumulators had lost its air pre-charge, consequently draining more fluid than usual from the reservoir, which had already been set at the minimum allowable filling level. Short lengths of glass tubing inserted into the pump suction lines allowed visual observation as to whether air was being introduced into the pumps. At a later date, when carrying this test to an extreme it was found that the pumps gave an audible warning of aeration that seemed out of all proportion to the percentage of air in the system.

(*g*) *Life Cycling Test*

Only after the operating characteristics of the systems had been proved satisfactory and within the specification was the life cycling test commenced. A "flight cycle" had been established which specified the number of operations of each service which would normally take place during one operational flight of the aircraft. (In this case, the Argus being a maritime reconnaissance aircraft one flight would be of considerable duration.) This "flight cycle" was multiplied by the estimated number of operational flights before complete overhaul, and taken as the duration of the life cycling test. The test rig was operated in 12 hour spells, the systems being under constant surveillance, with spot checks being made at regular intervals. For this purpose the visual window in the oscillograph permitted observation of the pressure changes as with an oscilloscope, without having to record the traces on paper.

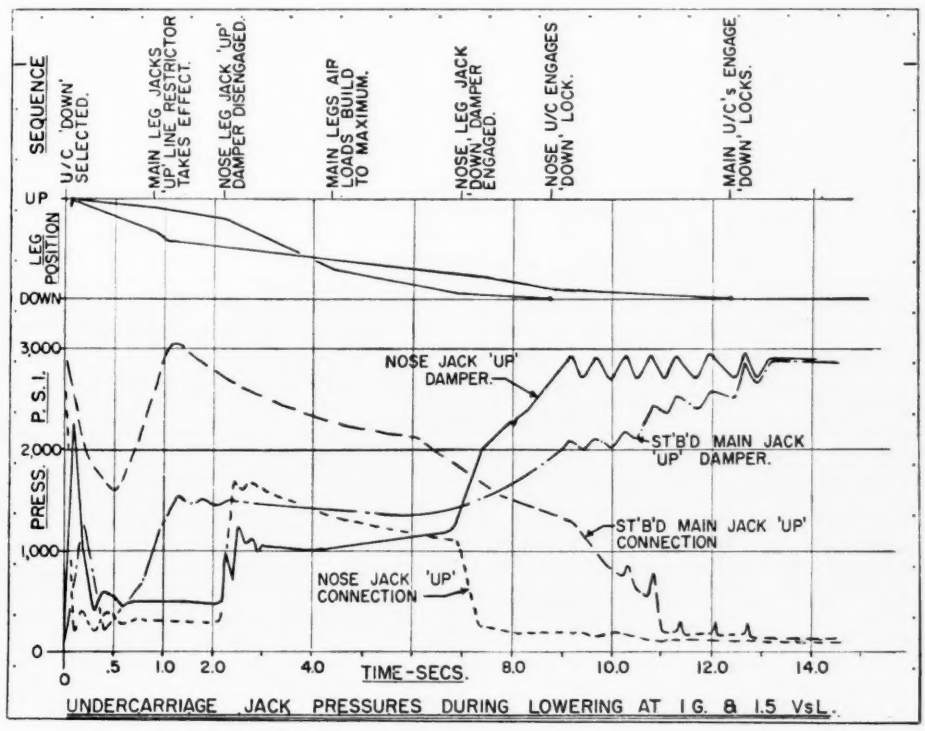

FIGURE 6. Typical graph obtained by reducing oscillograph record. The pressure fluctuations at the end of the cycle are typical of constant-displacement pumps controlled by a pressure regulator.)

During this phase of the testing it was found necessary to use the cooling coils to keep the fluid temperatures within limits, as the systems were being operated at a rate far in excess of the normal system requirements. Several points were brought to light which required further development work, and each problem was investigated and settled before continuing with the test.

At the completion of the test, salient pressure and back-pressure checks were repeated, and compared with results obtained before life cycling. All system filters and selected components were stripped and examined.

DATA COMPILED

By now it was considered that sufficient information regarding the characteristics of the system's performance had been compiled to form a sound basis for the flight test programme to be undertaken on the first aircraft. In addition, however, it was required to establish a method of measuring the percentage of air, if any, introduced into the pump delivery lines during manoeuvres within the aircraft limiting attitudes.

It was discovered on the test rig that with a pressure transducer installed close to the pump outlet the pressure pattern recorded on the oscillograph assumed a distinct and different pattern with small changes in the percentage of air introduced into the pump suction line. A series of these patterns was established by recording pump output pressures on the rig with known percentages of air being introduced.

The same transducer and oscillograph when mounted in the aircraft will produce records which can be compared with those obtained on the test rig, enabling an estimation of the aeration to be made.

CONCLUSION

Now that test flying is in progress, the flight information becoming available is agreeing closely with figures obtained on the test rig. The recordings made during final line and pre-flight tests on the aircraft have also been evaluated against the test rig. In both cases comparison shows that the condensing of the aircraft layout into a confined space did not adversely affect the accuracy of the rig data.

The success of the test rig was felt to be mainly due to having completed all the tests prior to the aircraft flying for the first time. The comprehensive instrumentation uncovered peculiarities in the systems which would have otherwise passed unnoticed.

The future rôle of the rig is three-fold. Firstly, to be used for the test and development of future modifications before their being embodied in the aircraft. Secondly, to be used to simulate and investigate flight snags as they arise, and thirdly to be used for the training and familiarisation of personnel with the hydraulic systems prior to working on the aircraft.

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The Plastic Bending of Heavily Curved Beams

by

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IT IS SHOWN that when heavily curved circular beams of constant cross section are subjected to a compressive load along the " open " diameter, the load for the start of significant deformation as indicated by the reduction in diameter along the line of action of the load, may be estimated by the use of rectangular plastic stress blocks based on the yield stress of the material. Comparison of the experimental values obtained on specimens of duralumin and mild steel with those predicted theoretically are, on the whole, only slightly underestimated.

INTRODUCTION

Consider a curved semi-circular beam loaded as shown in Fig. 1. The dangerous or critical section is assumed to be that of AB; the dimensions of this cross section are given in Fig. 2. As the load W increases from zero, the elastic behaviour of the beam will be displayed by a linear relationship between W and, say, the vertical deflection or the reduction in outer diameter of the ring. After the yield stress at the intrados—and later the extrados—on this section has been reached the plastic regions will continue to extend, although separated by an elastic core. If the beam is assumed to be made of an ideal material which is rigid-perfectly plastic, the stress-strain of which is as shown in Fig. 3, where Young's modulus is infinite and where plastic flow once started continues without hardening, then no deflection of the beam can occur as long as the inner core referred to is elastic. When the two plastic zones meet, complete collapse of the beam is possible; the load at which this collapse occurs will be called the collapse load. For the ideal material there would of course be no linear relationship between W and the deflection; that there is in fact such a relationship was asserted in order to accommodate knowledge of elastic deflections. However, when once the collapse load has been reached it is clear that deflections should increase at a more rapid rate (and not necessarily linear) than hitherto, so that by examining the deflection/load curve for a given beam, it should be possible to distinguish the point where there is a significant transition from elastic to plastic behaviour. Although all common ductile materials are to some extent strain-hardening, yet in those in which the strain-hardening rate is low and which also possess a well defined "knee," there is a reasonable approach to the ideal material. This model material is generally of most use in metal forming processes where imposed plastic strains are many times larger than the elastic strains and it is less accurate to apply it in cases

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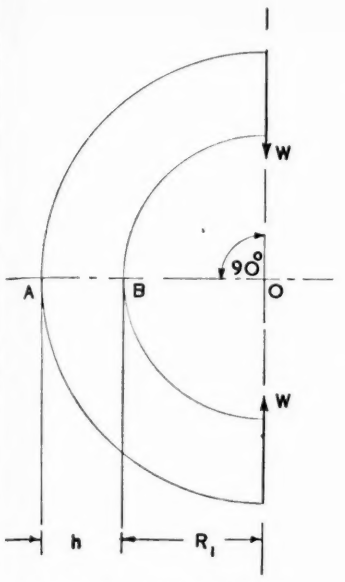


FIGURE 1. Side view of beams.

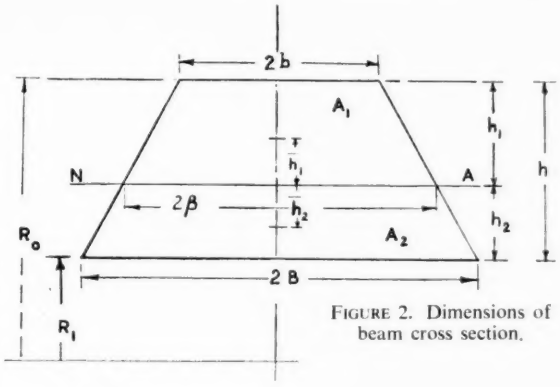


FIGURE 2. Dimensions of beam cross section.

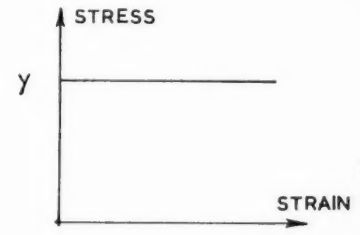


FIGURE 3. (*left*). Stress-strain curve of ideal rigid-perfectly plastic material.

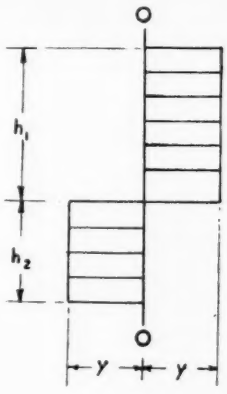


FIGURE 4. Assumed stress distribution across dangerous section.

such as the present one where the elastic and plastic strains are of the same order. Its use here is justified not only because it enables the behaviour to be apprehended intuitively, but also because the consequential mathematical analysis is simple to apply and easy to follow. This analysis is offered as a possible design approach because it requires only limited mathematical competence and yet will yield results of adequate accuracy. It should be further noted that the analysis takes no account of strains and ignores possible elastic changes in shape.

CALCULATION OF THE COLLAPSE LOAD

(i) *Trapezoidal Cross Section*

The stresses across the dangerous section are tensile over the outer portion of the beam and compressive over the inner portion. When collapse is imminent all the material across this section is yielding and it is assumed that the whole of it has reached the yield stress, so that the stress distribution is as shown in Fig. 4; this consists of two " rectangular " stress blocks, the stress being tensile over area A_1 and compressive over area A_2 (*see* Fig. 4). Along the line NA (Fig. 2) there is, theoretically, a stress discontinuity from $+Y$ to $-Y$, but in reality over the small region on either side of NA the stress is elastic, although changing very rapidly. The calculation of the collapse load proceeds as follows and the meaning of the various symbols will be clear from Fig. 2.

$$A_1=(b+\beta)h \text{ and } A_2=(\beta+B)h \quad . \quad . \quad (1)$$

$$\bar{h}_1=h_1(2b+\beta)/[3(b+\beta)] \text{ and } \bar{h}_2=h_1(\beta+2B)/[3(\beta+B)] \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where $\bar{h}_1$ and $\bar{h}_2$ are the distances of the centroids of A_1 and A_2 from NA.

Also

$$h_1=h(\beta-b)/(B-b) \text{ and } h_2=h(B-\beta)/(B-b) \quad . \quad (3)$$

Now from considerations of the equilibrium of forces on one half of the beam

$$W/Y=A_2-A_1 =h(B^2+b^2-2\beta^2)/(B-b) \quad . \quad . \quad (4)$$

using (1) and (3).

For moment equilibrium about O, it is found that

$$W\rho/Y=A_2\bar{h}_2+A_1\bar{h}_1$$

and again using (1), (2) and (3) this reduces to

$$W\rho/Y=h^2[2(B^3+b^3)-3\beta(B^2+b^2)+2\beta^3]/[3(B-b)^2] \quad (5)$$

where $\rho=R_1+h_2$.

From equations (4) and (5) it follows that

$$\beta^3-\frac{3}{2h}\left[R_1(B-b)+hB\right]\beta^2+\frac{3R_1}{4h}(B^2+b^2)(B-b)+ +\frac{B(B^2+3b^2)-2b^3}{4}=0 \quad . \quad . \quad (6)$$

Putting $x=\beta/B$, $y=b/B$ and $z=R_1/h$, expression (6) becomes

$$x^3-\frac{3}{2}\left[z(1-y)+1\right]x^2+\frac{3}{4}z(1+y^2)(1-y)+ +\frac{1}{4}\left[(1+3y^2)-2y^3\right]=0 \quad . \quad . \quad . \quad (7)$$

Since y and z are usually given x can then be found from (7) and used in (4) to give W. Expression (4) put into non-dimensional form similar to that of (7) becomes

$$W/(R_1BY)=(1+y^2-2x^2)/[z(1-y)] \quad . \quad (8)$$

Usually it is of most interest to know how $W/(R_1BY)$ varies with R_1/h for a given value of b/B and this is best obtained not by solving for x in (7) for various values of

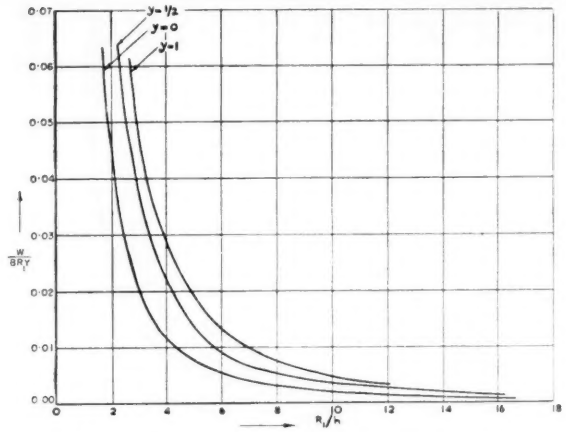


FIGURE 5. Variation of $W/(R_1BY)$ with R_1/h for $1{\cdot}6<R_1/h<16$.

z and the fixed value of y, but by choosing values of x and then determining z, *e.g.*:—

From (7),

$$z=[(4x^3-6x^2+1)+y^2(3-2y)]/\ [3(1-y)\{2x^2-(1+y^2)\}] \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

If $y=\frac{1}{2}$, put $x=\sqrt{[\frac{1}{2}(1+y^2)]}-\delta=\sqrt{(5/8)}-\delta$, and substituting in (9), yields after some manipulation

$$z\simeq 0{\cdot}0576\,n-0{\cdot}383 \text{ where } n=1/\delta.$$

Thus choosing values of δ, or n, corresponding values of z are obtained and ultimately $W/(R_1BY)$.

For purposes of evaluation in Figs. 5 and 6 the variation of $W/(R_1BY)$ with R_1/h is given for variously shaped sections, from the triangular in which $y=0$, through trapezoidal sections, $0<y<1$ to square sections in which $y=1$.

(ii) Square Cross Section

For the square section beam, expressions (7) and (8) fail to give solutions and in their place may be substituted the following expressions (*see* Fig. 7).

$$z=(2w^2-1)/[2(1-2w)] \quad . \quad . \quad (10)$$

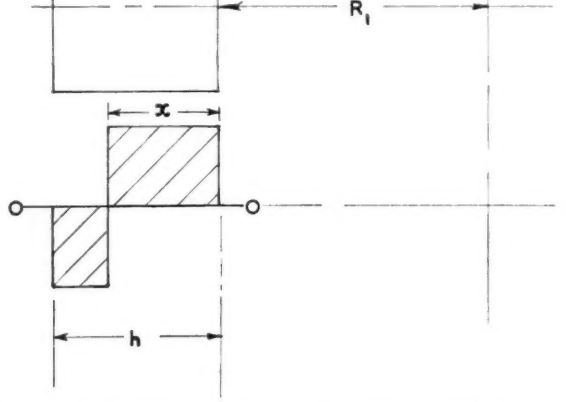


FIGURE 7. Dimensions for beam of rectangular cross section.

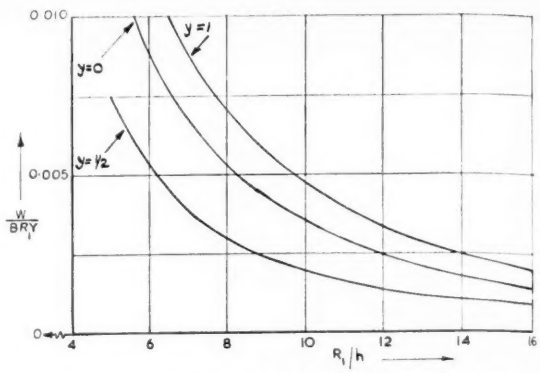


FIGURE 6. Variation of $W/(R_1BY)$ with R_1/h for $5<R_1/h<16$.

and $$W/R_1Y=(2w-1)/2 \quad . \quad . \quad . \quad (11)$$

where $w=\pi/h$, and $z=R_1/h$.

(iii) Circular Cross Section

Referring to Fig. 8 in which the stress discontinuity occurs at NN, the following two exact expressions for force and moment equilibrium respectively, can be derived

$$W/Y=r^2(2\phi+\sin 2\phi) \quad . \quad . \quad (12)$$

$$\text{and } 3W\left(\frac{R_1}{r}+1+\sin\phi\right)\Big/(Yr^2)=2\{3\phi\sin\phi+\cos\phi(2+\sin^2\phi)\} \quad . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

If ϕ is small and putting $x=W/(Yr^2)$, these expressions reduce to

$$x\simeq 4\phi \quad . \quad . \quad . \quad . \quad (14)$$

$$\text{and} \quad x\simeq 4/3\left(\frac{R_1}{r}+1\right) \quad . \quad . \quad . \quad . \quad (15a)$$

$$\text{or} \quad W/(2rYR_1)=2/3\left(\frac{R_1}{r}+1\right)\left(\frac{R_1}{r}\right) \quad . \quad (15b)$$

and (15*b*) is represented graphically in Fig. 9, B now being taken to be $2r$.

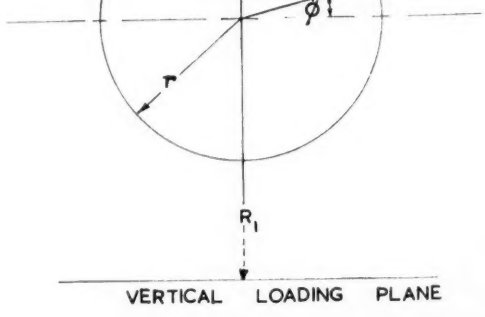


FIGURE 8. Dimensions for beam of circular cross section.

TABLE I

DURALUMIN

$Y = 29{\cdot}4$ tons/in.^{2}; $B = \frac{1}{2}$ in.; $R_0 = 1\frac{1}{4}$ in.

R_1 in.	h in.	$R_1/h = Z$	BR_1Y tons	△: $y=0$ lb.		⏢: $y=\frac{1}{2}$ lb.		□: $y=1$ lb.	
				Experimental	*Calculated*	*Experimental*	*Calculated*	*Experimental*	*Calculated*
1	$\frac{1}{4}$	4·00	7·35	345	348	665	660	950	908
$\frac{7}{8}$	$\frac{3}{8}$	2·33	6·43	920	900	1650	1615	2260	2230
$\frac{3}{4}$	$\frac{1}{2}$	1·50	5·52	1700	1785	2950	3080	4170	4025
$\frac{5}{8}$	$\frac{5}{8}$	1·00	4·60	3000	3110	4950	5100	6800	6670

TABLE II

MILD STEEL

$Y = 21{\cdot}6$ tons/in.^{2}; $B = \frac{1}{2}$ in.; $R_0 = 1\frac{1}{4}$ in.

R_1 in.	h in.	$R_1/h = Z$	BR_1Y tons	△: $y=0$ lb.		⏢: $y=\frac{1}{2}$ lb.		□: $y=1$ lb.	
				Experimental	*Calculated*	*Experimental*	*Calculated*	*Experimental*	*Calculated*
1	$\frac{1}{4}$	4·00	5·40	288	256	540	484	680	667
$\frac{7}{8}$	$\frac{3}{8}$	2·33	4·72	750	661	1250	1185	1740	1635
$\frac{3}{4}$	$\frac{1}{2}$	1·50	4·05	1375	1309	2300	2260	3260	2950
$\frac{5}{8}$	$\frac{5}{8}$	1·00	3·37	2280	2285	3950	3740	5120	4900

EXPERIMENTAL WORK

Experiments were carried out on beams made from (*a*) duralumin and (*b*) bright drawn mild steel bar. The stress-strain curve for both materials displayed a fairly sharply defined yield point but that of the duralumin is especially noteworthy as approximating well to the ideal elastic-perfectly plastic material.

The outer diameter of all the duralumin and the mild steel beams was $2\frac{1}{2}$ in. The cross section of the beams investigated was triangular ($y=0$), trapezoidal ($y=\frac{1}{2}$) and square ($y=1$). The value of B was in all cases $\frac{1}{2}$ in.

A small tensile specimen was cut from the original bar of each material and tested in a Hounsfield tensometer. The yield stress was then obtained from the load extension curves (*see* Fig. 10); the tensile yield stress y of the duralumin was 29·4 tons/in.^{2} and that of the mild steel 21·6 tons/in^2.

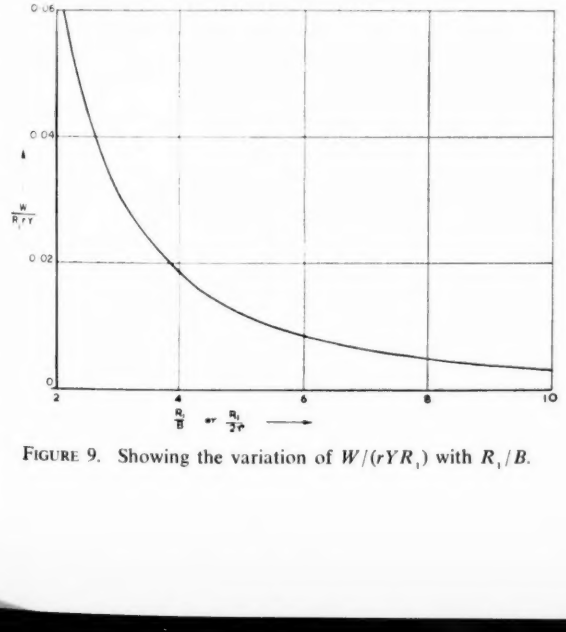


FIGURE 9. Showing the variation of $W/(rYR_1)$ with R_1/B.

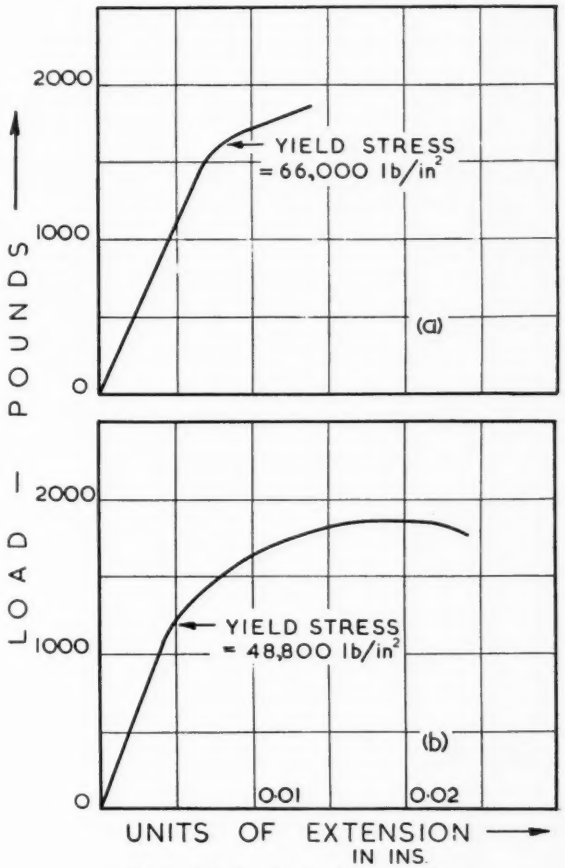


FIGURE 10. Load-extension curves for (*a*) duralumin and (*b*) mild steel.

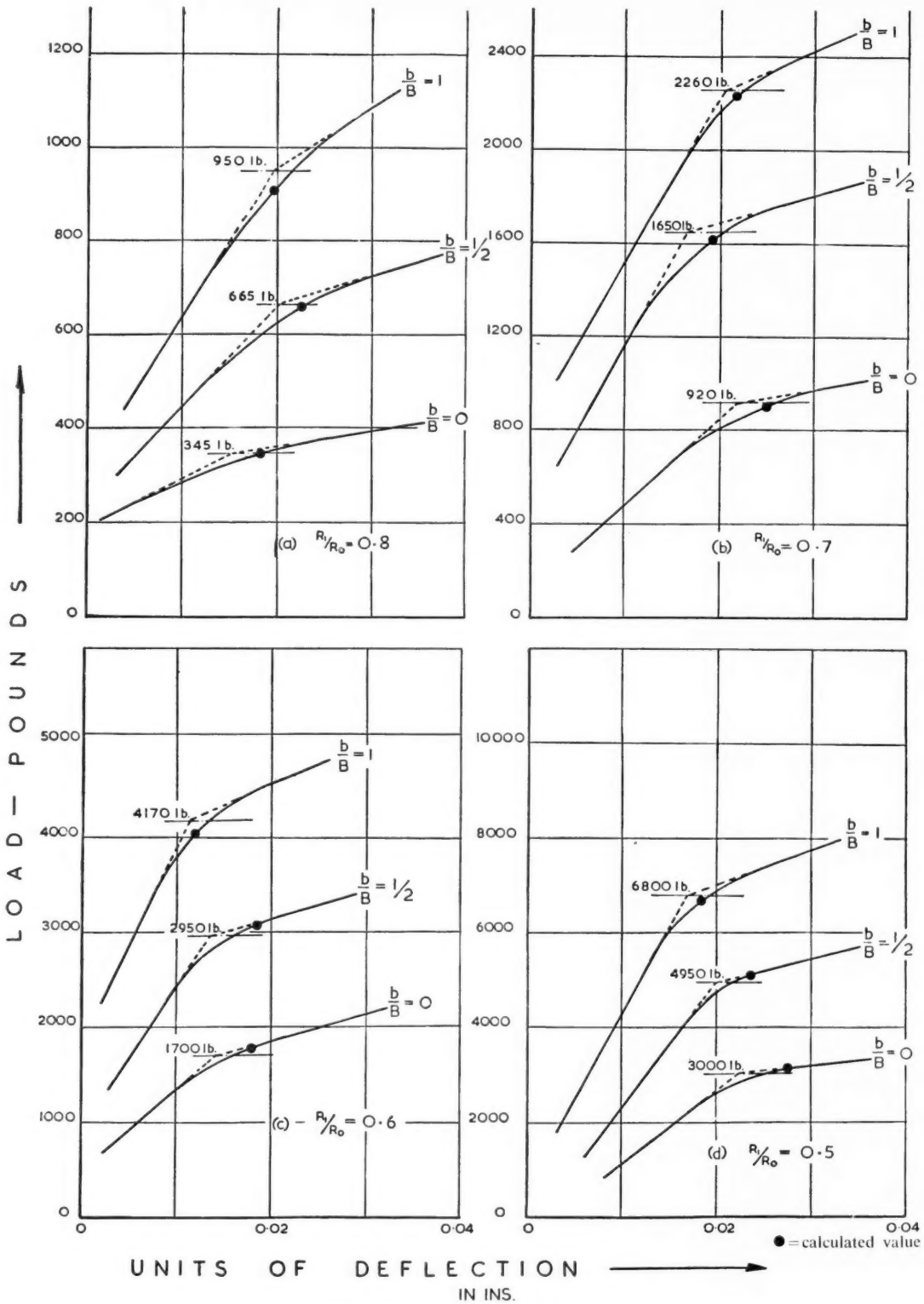


FIGURE 11. Load-deflection curves for duralumin.

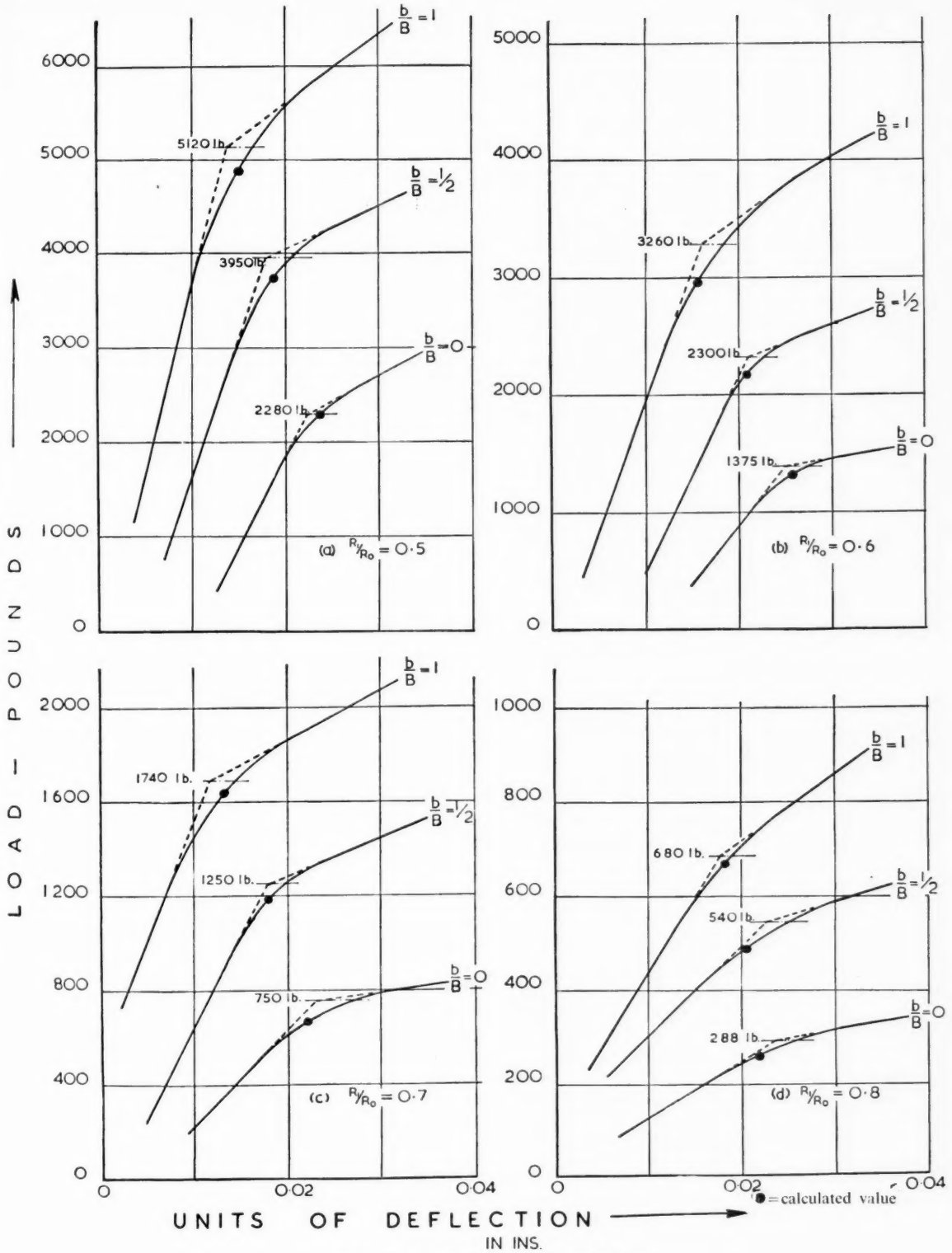


FIGURE 12. Load-deflection curves for mild steel.

All beams were machined from solid bar. The compressive load was applied in a light testing machine, which had been calibrated using a proving ring, and the diametral compression was measured as the load increased. The experimental set-up is the same as that described in a previous paper[1].

The load-deflection curves as obtained for all tests are shown in Figs. 11 and 12.

EXPERIMENTAL RESULTS

For each test the collapse load is obtained from the appropriate load-deflection curves which are given in Figs. 11 and 12 and is taken as the point of intersection of the plastic-elastic and the elastic lines. The corresponding load on the actual experimental curve is then obtained as indicated.

These loads are compared with those predicted analytically in Tables I and II.

DISCUSSION OF RESULTS

(*a*) *Duralumin*

Comparison of the experimental and calculated values for this material agree in all instances to better than ± 4 per cent. This degree of agreement is surprisingly good.

(*b*) *Mild Steel*

Apart from the experiments with the triangular section beams, the calculated load derived is usually about 7 per cent below the actual experimental value. This is no doubt due in large measure to the strain-hardening which takes place. To obtain a closer degree of accuracy in the predicted load an empirical formula could be used by multiplying the calculated value as derived in the calculation of the collapse load above by a constant factor of 1·07. But to omit this factor and adhere simply to that calculated would imply that a conservative estimate had been made and that a sizable reserve of strength remained in the member.

CONCLUSIONS

For materials having the form of stress-strain curve shown by duralumin, the expressions derived above, on the assumptions of rectangular (plastic) yield stress blocks across the critical section, for predicting the load at which sizable deformation commences, is adequate and satisfactory for all practical purposes. For a material which has a strain-hardening rate that is not small, the expressions tend to underestimate the collapse load by about 7 per cent.

The ideas used for deriving the calculated values of the collapse load are simple to appreciate and require the use of only the simplest mathematics, for which reason, the approach may command itself to designers.

ACKNOWLEDGMENTS

The authors wish to express their thanks to Mr. R. Fisher for his assistance in preparing some of the drawings.

REFERENCE

1. JOHNSON, W. (1956). *Journal of the Royal Aeronautical Society*, July 1956.

Empirical Equations for the Thrust Generated by an Ideal Supersonic Nozzle

by

P. N. ROWE

(*High Speed Fluid Kinetics Laboratory, Department of Chemical Engineering, Imperial College, London*)

NOTATION

A_e	cross-sectional area of nozzle exit plane—L^2
A_t	cross-sectional area of nozzle throat plane—L^2
a_0, a_1, a_2	coefficients in empirical area ratio equation
b	dimensionless thrust $= F/p_oA_t$
b_{max}	optimum dimensionless thrust, *i.e.* when $p_e = p_a$
B	a function of γ
b_0, b_1, b_2	coefficients in the empirical dimensionless thrust equation
D	a constant
F	nozzle thrust—ML/T^2
p_a	atmospheric (ambient) pressure—M/LT^2
p_e	pressure at nozzle exit plane—M/LT^2
p_o	reservoir (stagnation) pressure—M/LT^2
γ	specific heat ratio

Received 20th September 1957.

The dimensionless thrust generated by supersonic flow through a convergent-divergent nozzle is given by Ref. 1,

$$b = F/p_oA_t = D - (A_e/A_t)(p_a/p_o) \quad . \quad . \quad . \quad (1)$$

which takes its optimum value, b_{max} when $p_e = p_a$.

For ideal one-dimensional flow, the relationship between A_e and p_e is given by

$$A_e/A_t = \frac{\gamma-1}{2\gamma} B \left(p_e/p_o\right)^{-\frac{1}{\gamma}} \left[1 - \left(p_e/p_o\right)^{\frac{\gamma-1}{\gamma}}\right]^{-\frac{1}{2}} \quad . \quad (2)$$

and the optimum dimensionless thrust by

$$b_{max} = B\sqrt{\left[1 - \left(p_a/p_e\right)^{\frac{\gamma-1}{\gamma}}\right]} \quad . \quad . \quad . \quad . \quad . \quad (3)$$

where

$$B = \gamma \left(\frac{2}{\gamma+1}\right)^{\frac{\gamma+1}{2(\gamma-1)}} \left(\frac{2}{\gamma-1}\right)^{\frac{1}{2}} \quad . \quad . \quad (4)$$

From equations (2) and (3), the constant D in equation (1) can be evaluated and thence the thrust of an ideal nozzle at any pressure ratio provided that no separation occurs.

Equations (2) and (3) are tedious to evaluate and it is not easy to estimate the effect of changes in γ.

TABLE I

	0	1	2
a_0	0·02038	−0·09472	0·07882
a_1	−10·560	18·994	−3·860
a_2	98·93	−127·20	15·29
b_0	4·469	−3·6028	1·1220
b_1	−77·56	84·72	−25·1
b_2	904·6	−1077·2	339·7

These equations can be converted to the empirical forms

$$A_t/A_e = a_0 + a_1(p_e/p_o) + a_2(p_e/p_o)^2 \quad . \quad (5)$$

and

$$b_{max} = b_0 + b_1(p_a/p_o) + b_2(p_a/p_o)^2 \quad . \quad (6)$$

where the coefficients are given by

$$a_0 = a_{00} + a_{01}\gamma + a_{02}\gamma^2 \quad . \quad . \quad (7a)$$

$$a_1 = a_{10} + a_{11}\gamma + a_{12}\gamma^2 \quad . \quad . \quad (7b)$$

and so on.

Table I lists the constants in equations (7*a*) and so on, *which are valid only within the range* $p/p_o = 0{\cdot}01 - 0{\cdot}05$ (*i.e.* $p_o/p = 100 - 20$) *and* $\gamma = 1{\cdot}1 - 1{\cdot}5$.

Within these limits, equation (5) will estimate the area ratio with a maximum error of ±1·00 per cent and an average error of ±0·57 per cent. Equation (6) will estimate the optimum dimensionless thrust with a maximum error of ±0·70 per cent and an average error of ±0·30 per cent. The error in the difference between neighbouring values is less than this.

TABLE II

	a_0	a_1	a_2
$\gamma = 1{\cdot}1$	0·011559	5·6629	−22·49
= 1·2	0·020217	6·6745	−31·70
= 1·3	0·030450	7·6089	−40·60
= 1·4	0·042259	8·4661	−49·19
= 1·5	0·055645	9·2461	−57·48

TABLE III

	b_0	b_1	b_2
$\gamma = 1{\cdot}1$	1·8635	−14·739	130·72
= 1·2	1·7613	−12·040	101·13
= 1·3	1·6816	−9·843	78·33
= 1·4	1·6242	−8·148	62·33
= 1·5	1·5893	−6·955	53·13

Tables II and III give values of the coefficients *a* and *b* for a range of values of γ.

REFERENCE

1. FRASER, R. P., ROWE, P. N. and COULTER, M. O. (1957). The Efficiency of Supersonic Nozzles for Rockets and Some Unusual Designs. *Proc. I. Mech. Eng. 171*, 1957.

Safety and Large Aircraft

by

A. H. CRAWSHAW, A.F.R.Ae.S.
(*Blackburn & General Aircraft Ltd.*)

OUR Journal is becoming less and less interesting. Anyone who doubts this should look back at some of the old smaller journals. It contains more and more mathematics and less and less engineering. The proportion of recipients who read it must be diminishing and this surely defeats its object.

This is an attempt to start a debate on a controversial issue of vital importance:—

Safety in Relation to the Large Aircraft.

If an aircraft carries hundreds of people its safety is hundreds of times more important than that of an aircraft carrying only a few. It used to be thought that if a part were properly designed with full knowledge of the conditions and adequate factors of safety, it was safe. This is a conceited attitude. The trouble is that no one has full knowledge, and conditions may be decided by the weather and/or human errors. I believe it was a grave error of the aircraft industry to accept a factor of 2 only as being sufficient for a pressure cabin when a factor of 5 or 6 was considered necessary for a boiler.

This factor is still officially considered sufficient but a clause has been added requiring a satisfactory fatigue life. This is begging the question, one might as well say the aircraft shall be safe. Who knows whether any given pressurised fuselage has a satisfactory fatigue life? An expensive test on one only establishes the life of that one, the next one has different material and different workmanship and different accidental damage and corrosion, and so on. Dr. Duncan suggested a scatter factor of 9. I suggest that the strength factor ought to have been immediately increased officially after the Comet disaster. This would have definitely increased the fatigue life. Perhaps we did not feel strong enough to admit the error.

When it was found that many aircraft flying were likely to suffer from fatigue failures, "safe lives" were estimated.

These safe lives are only probably true. The theory of probability can only be correctly applied to "populations" which are "under control." Now the unexpected things which cause accidents are not under control. If they were they would not be allowed to happen.

The designers of future large aircraft will not be satisfied with components working within their safe life periods only, they will also consider what happens when *any* "critical element" fails.

This means that *all* critical elements must be so duplicated that they "fail safe." This is an old idea in the aircraft industry. Broken wires were considered for bi-planes and Imperial Airways required multiple engines.

For example, it may be very unlikely that a main elevator hinge will fail: but if it does, due to defective material (and latest crack detection methods show how unreliable our materials are) the results are catastrophic. Therefore elevators must be split so that some control is left when a failure does occur.

A large helicopter designed for carrying a large number of people will not be acceptable unless it is still safe after a blade has failed.

The arguments in the future will perhaps centre around how much safety is required after "a critical element" has failed. The American C.A.A. Requirements seem lenient in this respect.

(*Correspondence will be welcomed.—Editor*)

Received 31*st October* 1957.

Garden Party - 1957

THE SOCIETY'S annual Garden Party was held for the second year running at Vickers-Armstrongs' Aerodrome at Wisley, Surrey on 15th September. The Host was Sir George Edwards, the Managing Director who is also the Society's President for 1957. Sir George and Lady Edwards received members and their guests in a marquee out of the cold and rather penetrating wind while the smartly turned-out Military Band of Vickers-Armstrongs (Aircraft) Ltd. provided light entertainment.

The party was held in September instead of July because the Sixth Anglo-American Conference was due to be concluded at Folkestone on 12th September and so it was decided to hold the Party on the following Sunday. The idea was to give as many as possible of the Society's American guests and their ladies a chance of attending.

Some 4,600 people were present including nearly 550 children, so the organisers' efforts were well rewarded.

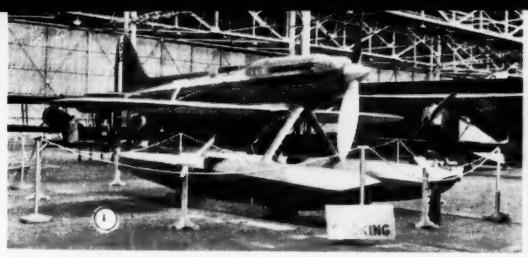
The occasion was also Battle of Britain Sunday and coincided with the actual day in 1940 which became one of the most famous in our history. The Party was not part of the official celebration but the Programme contained a tribute in acknowledgment of the event.

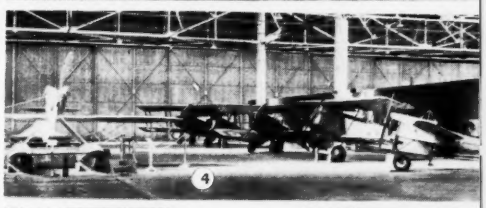
One of the principal attractions of the Society's Garden Parties since 1953 has been the Nash Collection of Veteran Aircraft. These are brought out of storage each year, erected and displayed in a suitably sheltered place. On this occasion, Vickers-Armstrongs had been able to provide a well-lit and well-warmed hangar.

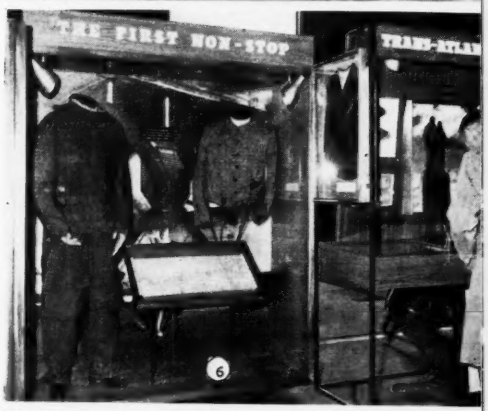
The "Stick and string" enthusiasts no doubt delighted in another look at the Sopwith Camel, its pugnacious nose contrasting with the more slender but angular nose of its traditional enemy, the Fokker D.VII standing nearby. The S.E.5A, standing between them looked strangely modern, showing a strong family likeness to the Gloster Gladiator, twenty years its junior.

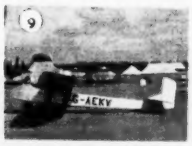
Next to the Fokker stood two famous training aircraft of the 1914-18 War, the Maurice Farman and the Caudron G.III while at the other end of the line was the most famous trainer of all, the Avro 504. Possibly the pride of the static display was the Vickers Supermarine S6B. This beautiful racing seaplane, one of two built for the last Schneider Trophy International Contest for seaplanes, in 1931, exceeded the existing world absolute speed record by reaching 379·05 m.p.h. It was lent for the Garden Party by the Corporation of Southampton. The static display also contained a large collection of excellent scale models lent by aircraft manufacturers and model clubs and there was one superb three foot span model of a Vickers Vimy, privately owned, in which everything except the engines appeared to work as in the prototype.

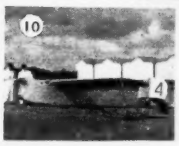
Vickers-Armstrongs showed their collection of mementos of the first Atlantic flight by a Vimy in 1919 and other interesting exhibits included a scale model of the centrifuge used by the R.A.F. Institute of Aviation Medicine for the simulation of "*g*" forces; an experimental pressure suit and a model of a launcher for the "Skylark" high-altitude research rocket, both being lent by the R.A.E., Farnborough: a D4 instrument-flying trainer lent by Air Trainers (Link) Ltd.; a 25-seater Universal life raft lent by R.F.D. and making its first public appearance; finally the famous copy of the Wright Brothers engine made by apprentices of the











1. Supermarine S6B.
2. Spitfire and Hurricane.
3. Spartan Arrow.
4. Some of the Nash Collection.
5. Wisley *en fête*.
6. Some of the Alcock and Brown Atlantic flight mementoes.
7. Blackburn B.2.
8. Fairey Swordfish
9. Kronfeld Drone.
10. English Electric Wren.
11. Tigers on the prowl.
12. Sir George and Lady Edwards receiving members and their guests.

Photographs 1-6 and 11 and 12. Courtesy of Vickers-Armstrongs (Aircraft) Ltd., 7, 9 and 10 A. S. C. Lumsden and 8 A. J. Jackson.

de Havilland Aeronautical Technical School and in working order.

This static display was one of the best ever seen at the Garden Party and its success is chiefly due to its collection and excellent accommodation by Vickers.

In addition to the Static Show, there were a large number of aircraft which had flown in but which did not take part in the Flying Display. These included sixteen French registered aeroplanes, and a U.S.A.F. Grumman Albatross from a Rescue unit based at Manston. The big amphibian, about the size of a Dakota, dominated the aircraft park. Altogether some 95 aircraft were present.

The flying display was not seriously affected by the wind although most pilots had a rough ride. The programme followed the pattern of previous years.

The pilots of some of the older aeroplanes confined their demonstrations to fast and slow passes in front of the spectators but there were several who put up as fine a show of aerobatics as one could want. The show opened with the highpitched whirring of David Ogilvy's Comper Swift. The little Pobjoy seemed to be in good voice as also did the Niagara of the graceful B.A. Swallow which appeared a little later. Then followed the two Tipsys, the Belfair of long-distance record fame and the tiny single-seat Junior whose sprightliness showed it to be far more grown up than it looked.

The Miles Aries appeared next followed by the G.A.L. Cygnet, the first British light aeroplane to go into production with a tricycle undercarriage, and the last surviving Hawker Tomtit. The cheerful clatter of the Tomtit's Mongoose engine gave way to the most

extraordinary, tortured whine of the Kronfeld Drone. Sounding like a Wasp with its propeller hard up against the fine-pitch stops, this converted glider caught everybody's attention. In the same ultra-light vein the English Electric Wren took off in about its own length aided by the fresh breeze and two energetic assistants at the wing tips. The Garden Party was the occasion of the formal handing-over of the Wren to the Shuttleworth Trust. Mr. W. O. Manning who designed it 35 years ago was there to take part in the occasion.

A demonstration by a Miles Hawk Trainer III was followed by three French visitors, a pair of Émeraudes and a Jodel all of which are powered by American flat-fours and are designed for home construction.

Perhaps the highlight of the afternoon was the joint display by the Spitfire flown by Jeffrey Quill and the Hurricane by A. W. Bedford. As happened last year, these two made the most of the occasion and gave a realistic demonstration of a low level dog fight and the snarl of the two Merlins brought back memories of filigree tracery above the fields of Kent and swastikas among the stooks of corn.

Three aircraft of American birth and Irish extraction came over from Dublin, a Piper Tri-Pacer, a Piper Apache and a Beechcraft Bonanza and their flying demonstrations, necessarily sedate as befitted their executive function, were followed by a lively performance by the Miles M.18, flown by H. B. Iles, this year's throttle-bender-in-chief. Two Edgar Percival E.P.9's followed, one of them gaily spraying water to show its abilities as a crop duster. Unfortunately, the "flying hat" himself was unable to be present.

The first of the new series of civil Prentice conversions looking very beamy and comfortable was followed by a S.A.A.B. Safir in Swedish Air Force uniform and the Blackburn B.2, its metal fuselage brightly polished and looking very smart. The one and only Hirtenberg H.S.9A was next on the programme, an example of the almost extinct "Parasol" monoplane.

By this time, the programme was nearing its end but strange things were happening. The Swordfish was taking on its crew and what an "equipage" it was. Peter Twiss was driving but he had no less than four back seat drivers, all of them test pilots! One of them sported a top hat and as the long suffering "Stringbag" drifted backwards and forwards in front of the crowd at surely no more than sixty knots, these weird characters bowed and waved in the best circus tradition. Occasionally feet appeared over the side instead of faces. The whole affair was a lighthearted romp and it only lacked a pair of bicycles lashed to the wings to be worthy of Bertram Mills. The Fulmar flew with the Swordfish much of the time with the aid of a good deal of flap and, no doubt a good deal of skill in view of the bumpy conditions.

The mention of the roughness of the air brings us to the last item on the programme. The Tiger Club from Croydon brought over nine Tiger Moths (including the oldest in existence) equipped in various ways for different functions from taxi-work and photography to aerobatics and sporting flying. They took off in formation, flew extremely good formation patterns (and this included a formation loop) and rounded off a perfectly timed show with the nine aircraft flying over the President's Marquee in the letter "E," a pretty tribute to our Host. In between formation changes, spectators were treated to a very neatly executed series of individual aerobatics by C. A. Nepean Bishop including some inverted flying which required some tricky juggling with the fuel controls as, apparently, the special inverted fuel system was not functioning satisfactorily.

So ended a very pleasant flying programme, splendidly organised and most efficiently run.

So many individuals contribute to the success of such a show that it is impossible to mention everybody by name. In the very limited space available may we express thanks to the organisers, the pilots, the ground staff and all who gave so much of their time and energies to make this Garden Party a success. This applies particularly to Vickers-Armstrongs (Aircraft) Ltd. for the excellent arrangements for their guests and also to the caterers. To Sir George and Lady Edwards, our Host and Hostess go special thanks.—A.S.C.L.

In addition the Council would like to thank the following:—

Mr. Addicott, Mr. G. R. Bryce, Mr. R. Darch, Mr. R. Edmonds, Mr. Charles Gardner, Mr. D. Morgan and Mr. J. Wheeler of Vickers-Armstrongs (Aircraft) Ltd.; Mr. E. R. Howse and the Vickers-Armstrongs (Aircraft) Military Band; Dr. A. H. Lankaster and Dr. R. Wilson of the Vickers-Armstrongs (Aircraft) Ltd. Weybridge Works Medical Staff and volunteers from the Works' First Aid Group and apprentices from Vickers-Armstrongs (Aircraft) Ltd. Weybridge Works; Dr. A. Buchanan Barbour and the British European Airways Mobile Medical Unit.

Air Service Training Ltd.; Air Trainers (Link) Ltd.; Aircraft Associated Ltd.; Airways Aero Club; the Automobile Association; Aviation Traders Ltd.; Avions Fairey S.A.; Blackburn and General Aircraft Ltd.; British Legion Car Attendants Co. Ltd.; the de Havilland Aircraft Co. Ltd.; the de Havilland Technical School; R.A.F. Apprentices from Halton; Derby Aviation Ltd. (Elstree Flying Club); the Service Department of Dunlop Rubber Co. Ltd.; Edgar Percival Aircraft Ltd.; English Electric Co. Ltd.; Fairey Aviation Co. Ltd.; Hawker Aircraft Ltd.; Irish Air Charter Ltd.; Jackaroo Aircraft Ltd.; John Gardner Caterers Ltd.; the Ministry of Supply; Royal Aircraft Establishment; R.A.F. Institute of Aviation Medicine; R.F.D. Company Ltd.; Royal Swedish Air Force; The Director of the Science Museum; Shell-Mex and B.P. Ltd.; Southport Aero Club; No. 604 Squadron Flying Club; the Spartan Group; Surrey Constabulary; United States Air Force; and Vickers-Armstrongs (Aircraft) Ltd. Supermarine Works.

HIGH ALTITUDE AND SATELLITE ROCKET

Symposium 18th - 20th July 1957

RECENT events have given added weight to the importance of the symposium held at Cranfield on 18th-20th July 1957, under the joint auspices of the Society, the British Interplanetary Society, and the College of Aeronautics.

The symposium was attended by more than 180 delegates from the aircraft industry, research establishments and universities, and had an international flavour with representation from most European countries, including Poland and the U.S.S.R., and from America. It was noteworthy as the first occasion on which the Society has ventured into this new and increasingly important field. It was also encouraging to find that there was a real appreciation of the part which aeronautical engineers and scientist must play in developing space vehicles.

A total of twelve papers was presented, ranging from the scientific uses of the satellite rocket to the medical problems of space flight and covering such specialist subjects as the design of large rocket vehicles, propulsion problems, guidance problems, re-entry to the atmosphere, and materials. The discussions were lively and attracted much attention in both the daily and the technical Press at home and abroad. They will be published with the papers in a volume of Proceedings in the near future. This will be available for purchase by all who are interested.

In addition to the lecture sessions, opportunity was provided for informal discussion by the residential nature of the symposium and the several social functions which were arranged. All these provided an enjoyable and memorable background to the first symposium of this kind to be held in Britain.

At the conclusion of the symposium an exhibition was organised to display and demonstrate many rocket components and techniques. Exhibits included the British Skylark high altitude sounding rocket, a sectioned Veronique rocket from France, examples of current British rocket engine practice, demonstrations of instrumentation for upper atmosphere research by members of the staff of University College, London, and the University of Birmingham, demonstrations by the College of Aeronautics of supersonic wind tunnels, rocket propellants and rocket engine firings.

This exhibition was open to all members of the Society and was visited by a number of parties organised by the Branches. Altogether some 1,500 people attended.

The Council has noted the success of the symposium with pleasure and wishes to record its appreciation and thanks to all the individuals who assisted in the arrangements. Also it is grateful to the firms and organisations which so willingly loaned material and equipment for the exhibition.—A. D. BAXTER.

The following is the list of lectures given:—

Thursday, 18th July

Scientific Uses of High Altitude Rockets and Artificial Satellites. Professor H. S. W. Massey (University College, London)
The Earth Satellite Programme. Milton Rosen (Naval Research Laboratory, Washington)
The British Upper Atmosphere Sounding Rocket. W. H. Stephens (R.A.E.)
Some Propulsion Problems of High Altitude Rockets. Professor A. D. Baxter (College of Aeronautics)
Design Problems of Large Rockets K. J. Bossart (Convair—Astronautics)

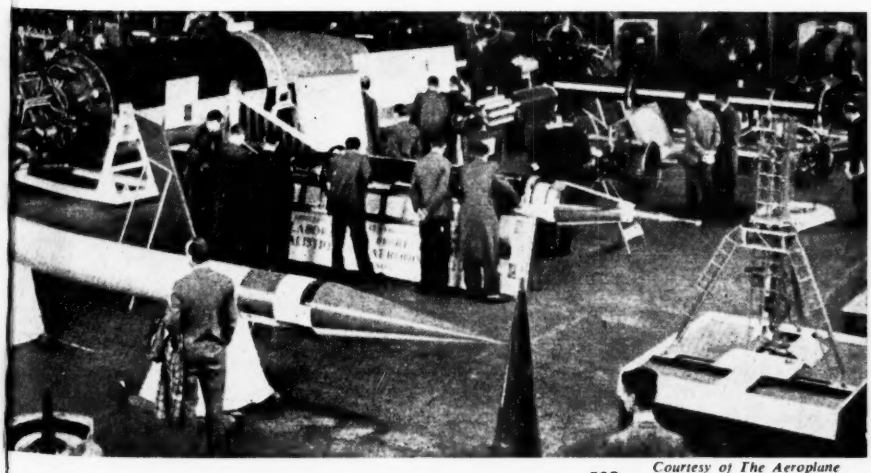
Friday, 19th July

Re-entry and Recovery. Dr. W. G. Hilton (Armstrong-Whitworth)
Dynamics of a Dissociating Gas-Non-Equilibrium Theory. Dr. N. C. Freeman (N.P.L.)
Materials for Re-entry Vehicles. Dr. P. Murray (U.K.A.E.A. Research Group, Harwell)
Some Problems of Telemetry, Instrumentation and Guidance. Dr. A. W. Lines (R.A.E.)
Current Picture of Research in Bio-Astronautics. Dr. H. G. Clamann (U.S.A.F. School of Aviation Medicine)
Psycho-Physiological Hazards of Satellite Flight. Lt. Col. J. P. Henry (U.S.A.F. Air Research and Development Command)

Saturday, 20th July

Future Developments in Rocket Propulsion. Dr. L. R. Shepherd (A.E.R.E.)

A view of the exhibition. *Right*: Professor Boris Petrov who greeted the delegates on behalf of the Soviet Academy of Sciences, with Mr. W. Geisler, Poland. During the Symposium Professor Petrov said that "in the Soviet Union during the IGY the first launching of a man-made satellite" would be made. He also said that there would be thirty vertical rocket firings during 1957 from one of three zones.



Courtesy of The Aeroplane

Courtesy of G. V. E. Thompson, Esq.

Sixth Anglo-American Aeronautical Conference

LONDON - FOLKESTONE 1st - 12th September 1957

FOR THE FOURTH time in the past ten years the Anglo-American Aeronautical Conference was held in England and the Society was host this year to more than one hundred delegates from the Institute of the Aeronautical Sciences.

This Sixth Anglo-American Aeronautical Conference was held at Folkestone from 9th-12th September 1957 but, as always, a number of visits to the Industry and research establishments were arranged for American delegates in the preceding week.

Appropriately, therefore, the Conference began at the offices of the Society when most of the 119 American delegates, some accompanied by their wives, and many of the 520 British delegates and their wives, were entertained by the President and Council to cocktails on Sunday evening 1st September 1957. This was a happy occasion during which old friendships were renewed and many new ones were begun for, although some of the American delegates were attending their third, fourth—or even fifth and sixth—conference, the majority were newcomers.

Thereafter American delegates in different groups began a busy week of visits as follows:—

Monday 2nd September

1. Fairey Aviation Co. Ltd., White Waltham.
2. National Gas Turbine Establishment, Pyestock.
3. London Airport and B.E.A. Engineering Base.

Tuesday 3rd and Wednesday 4th September

S.B.A.C. Display, Farnborough.

Thursday 5th September

1. Short Brothers and Harland Ltd., Belfast (staying overnight).
2. Vickers-Armstrongs (Aircraft) Ltd., Weybridge, and on to Derby for the night.
3. College of Aeronautics, Cranfield, staying overnight.

Friday 6th September

1. Sir W. G. Armstrong-Whitworth Aircraft Ltd., Coventry (those delegates who had been visiting Belfast).
2. Rolls-Royce Ltd., Derby.
3. Royal Aircraft Establishment and Aircraft Research Establishment, Bedford.

Some 60 American ladies and young people accompanied the American delegates to the Conference and, for them, during this first week the following tours were arranged: London with dinner at the Royal Festival Hall followed by a theatre; Hampton Court, Runnymede and Windsor followed by tea with Lady Edwards at her home; Oxford; and Stratford-on-Avon, which included Warwick Castle and an evening performance at the Shakespeare Memorial Theatre, returning to London the next day by way of the Cotswolds.

During the weekend of 7th and 8th September both American and British delegates assembled at Folkestone for the Conference itself. The Hotel Metropole was the headquarters of the Conference, all social functions and technical sessions being held in the hotel.

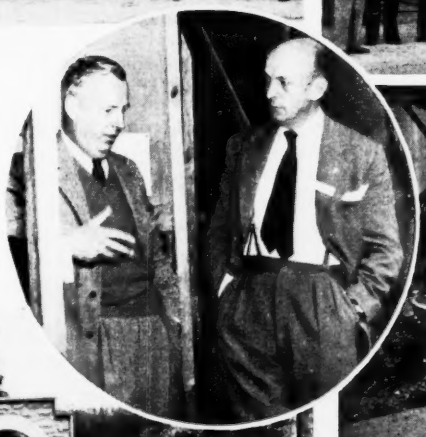
Above: The Opening Session of the Sixth Anglo-American Aeronautical Conference on Monday 9th September 1957 in the Ballroom of the Hotel Metropole. *From left to right*: S. Paul Johnston, Director I.A.S.; The Deputy Mayor of Folkestone, Councillor Brown; Sir George Edwards, President R.Ae.S.; Mundy I. Peale, President I.A.S.; and Dr. A. M. Ballantyne, Secretary, R.Ae.S. *Left*: A general view of the Delegates assembling for the Opening Session.

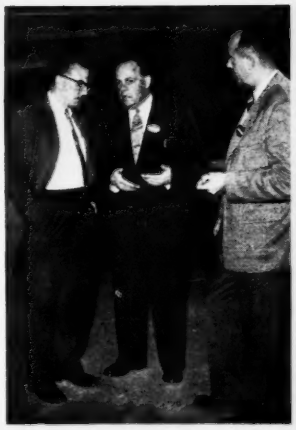
Photographs by courtesy of
HALKESWORTH WHEELER

Above: A group of Delegates at the Fairey Aviation Co. Ltd., White Waltham.

Top right: Delegates at Vickers-Armstrongs (Aircraft) Ltd., Hurn factory.

Right: Mr. Mundy Peale, President of the Institute of the Aeronautical Sciences and Sir George Edwards, President of the Society.





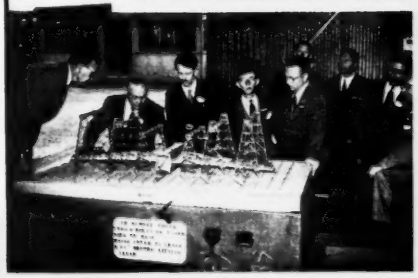
Above: Some of the ladies who had tea with Lady Edwards at her home, *left to right*, Mrs. Paul Johnston, Mrs. N. E. Rowe, Mrs. Elmer Sperry, Mrs. D. L. Hollis Williams and Mrs. Frederick Felberg.

Right: Mr. R. R. Dexter, Secretary of the Institute and (*left*) Mr. J. Maitan, Controller of the Institute, at Short Brothers in Belfast.

Above: Mrs. Peale, Lady Edwards, Mrs. Grumman and Miss Angela Edwards in the Edwards' garden.

Left: Mr. B. K. Bucey, of Boeings, and Mr. C. J. McCarthy, Past President of the Institute, during the visit to Shorts.

Right: Delegates examining a model of full-scale wing testing facilities at Belfast.



Below: Delegates who visited the National Gas Turbine Establishment at Pyestock.

Below right: A Group, which includes Dr. Clark B. Millikan and Dr. H. L. Dryden, at the Royal Aircraft Establishment, Bedford.

The Social functions included the opening reception on the Monday night, a reception by the Mayor and Mayoress of Folkestone, Councillor and Mrs. L. V. Fowler, with buffet supper and a cabaret on the Wednesday, and the Conference Dinner-Dance on the last night.

While delegates were attending the technical sessions tours were arranged each day for wives and families who accompanied the delegates. In addition to the 60 American ladies and young people some 135 British ladies and their families attended the Conference. The tours included visits to Canterbury, Dover Castle, the Museum of Costume at Eridge Castle, Tunbridge Wells, Rye and Winchelsea.

Four days were devoted to the technical sessions this year which meant that 16 lectures could be dealt with comfortably and there were no "double sessions"—except for the informal Discussion on Sandwich Construction which was arranged one afternoon and the continuation of the Discussion on V.T.O.L.-S.T.O.L. Aircraft, when some 50 delegates carried on the discussion on Mr. McKinney's lecture for the rest of the morning.

Although not the largest of the six joint Royal Aeronautical Society–Institute of the Aeronautical Sciences Conferences it was a most enjoyable one. The outstanding value for members of all such conferences has always been the friendships made and the opportunities of exchanging views with their opposite numbers.

The next Conference is to be held in October 1959 in New York.

The Conference Programme

Although the Conference officially finished with the Dinner-Dance on 12th September, the Forty-fifth Wilbur Wright Memorial Lecture given this year by an American, Dr. Clark B. Millikan, had been arranged for the 13th September and a number of Conference delegates attended this and the Society's Garden Party, which was held on Sunday the 15th September.

Monday 9th September

Morning

Opening of the Conference by the Deputy Mayor of Folkestone, Councillor Brown, the President of the Royal Aeronautical Society, Sir George Edwards, and the President of the Institute of the Aeronautical Sciences, Mr. Mundy I. Peale.

N.A.C.A. Research on VTOL and STOL Aeroplanes, Marion O. McKinney (Aeronautical Research Engineer, N.A.C.A. Langley Aeronautical Laboratory, Langley Field, Va.). *Chairman*: D. Keith-Lucas.

Nuclear Mobile Propulsion with Particular Reference to Aircraft, J. V. Dunworth (Head of Reactor Division, Research Group, U.K.A.E.A.). *Chairman*: Rear-Admiral Lawrence B. Richardson.

Afternoon

Control of Supersonic Propulsion Systems, John C. Sanders (Lewis Flight Propulsion Laboratory, N.A.C.A., Cleveland, Ohio). *Chairman*: Dr. E. S. Moult.

The Electrical Control of Power Plants, G. M. Sturrock (Ultra Electric Ltd.). *Chairman*: Dr. Edward R. Sharp.

Evening

Conference Reception.

Tuesday 10th September

Morning

Alleviation of Kinetic Heating Stresses, James Taylor (Head of Structures Research Division, Royal Aircraft Establishment). *Chairman*: Dr. Hugh L. Dryden.

Nine Years of Titanium Usage, Leo Schapiro and Emerson LaBombard (Douglas Aircraft Company, Inc., Santa Monica, California). *Chairman*: Sir Sydney Camm.

Afternoon

The Use of Non-Metallic Materials at High Temperatures, Dr. W. J. Strang (Bristol Aircraft Ltd.). *Chairman*: Dr. Clark B. Millikan.

Blast Loading of Aircraft Structures, Professor Raymond L. Bisplinghoff and Dr. Emmett A. Witmer (Massachusetts Institute of Technology, Cambridge, Massachusetts). *Chairman*: Dr. P. B. Walker.

Wednesday 11th September

Morning

Safety in Relation to Structural Damage, Dr. A. E. Russell (Director and Chief Engineer, Bristol Aircraft Ltd.). *Chairman*: Dr. T. P. Wright.

An Appraisal of Aeroelasticity in Design, with Special Reference to Dynamic Aeroelastic Stability, Martin Goland (Vice-President, Southwest Research Institute, San Antonio, Texas). *Chairman*: N. E. Rowe.

Afternoon

The Presentation of Information by Aircraft Instruments, A. Stratton (Royal Aircraft Establishment, Ministry of Supply). *Chairman*: Charles H. Colvin.

Increased Usable Lift through Boundary Layer Control, Charles W. Harper (Aeronautical Research Scientist, N.A.C.A., Ames Aeronautical Laboratory, Moffett Field, California). *Chairman*: Prof. H. B. Squire.

Evening

Reception by the Mayor of Folkestone. Buffet, Cabaret and Dancing.

Thursday 12th September

Morning

The Role of Experimental Hyperballistics in the Development of Future Aeroplanes and Missiles, Dr. H. H. Kurzweg (U.S. Naval Ordnance Laboratory, White Oak, Silver Spring, Maryland). *Chairman*: Dr. G. W. H. Gardner.

Design for Repairability of Civil Turbine Engines, A. H. Harvey-Bailey (Rolls-Royce Ltd.). *Chairman*: Charles J. McCarthy.

Afternoon

Aerodynamic Effects of Boundary Layer Unsteadiness, Franklin K. Moore (Cornell Aeronautical Laboratory, Inc., Buffalo, New York). *Chairman*: Air Marshal Sir Owen Jones.

The Human Pilot as an Aircraft Operator, Sqn. Ldr. T. C. D. Whiteside (R.A.F. Institute of Aviation Medicine). *Chairman*: Jerome Lederer.

Evening

Conference Dinner-Dance.

Graduates' and Students' Section

NATIONAL SERVICE

We have received a letter from the Ministry of Labour and National Service which provides a very clear picture of the present position about deferment for aeronautical engineers, and it is printed below: —

"There are arrangements under which indefinite deferment can be granted to science and engineering graduates for employment on specific high priority Government research and development projects, mainly in connection with the defence programme. Deferment is granted only in response to representations from the employing or contracting Government Department or Authority, for posts for which it has not been possible to recruit men without a national service liability. There is also a limit to the number of deferments that can be granted each year, in view of the needs of the Services for science and engineering graduates. We are unable to let you have details of specific types of employment for which graduate aeronautical engineers can be deferred but the posts would be mainly with firms engaged on Ministry of Supply Contract work.

"Men who are deferred under these arrangements are required to remain in the employment for which deferment has been given until they cease to be liable for national service on reaching the age of 26. A transfer to other employment can be considered only in special circumstances, *e.g.* when there is a change in priority or it is desirable in the national interest that a man should be switched to another project.

"This year an additional scheme has been introduced which allows men completing courses of study or training in 1957, and who have taken a *first class* honours degree in science or engineering, to be indefinitely deferred for *any* employment where they will use their qualifications.

"With regard to ex-craft apprentices, there are special arrangements under which (1) certain Government Establishments, and engineering firms, engaged on high priority defence work recognised by the contracting Government Department, or Authority, and (2) engineering firms nominated by the interested Government Department as engaged on specified categories of engineering production of the highest importance to exports, may apply for the deferment of their engineering ex-apprentices employed on such work. Deferment of this sort is limited to two years beyond the end of apprenticeship, with the overriding proviso that the ex-apprentice does not pass out of liability to call-up during the period, and that he remains with the employer in whose establishment he received his apprenticeship training. At the end of this special period of deferment, ex-apprentices are required to do their National Service."

The following letter has also been received: —

"Sir,

This letter is prompted by a letter 'Some thoughts on National Service' by 'Twenty Six year old' in the October JOURNAL. That he is slightly ashamed of his letter is shown by the fact that he has not signed his name. The Services are attacked as being inefficient; consider their difficulties, everything on a temporary short term basis and the intakes consisting of unwilling young men who have no intention of trying. Do young men not find inefficiency everywhere? Is there none in the aircraft industry?

All this is irrelevant. Our Government considers National Service necessary. In these days of shortage of staffs in all trades and professions there is no logical reason for any section being exempt.

'Twenty Six' will find that Technical Training is not everything; that power to influence others is important and this can be practised very well in the Services. 'The proper study of mankind is man.'"

Yours faithfully,

A. H. CRAWSHAW

Brough, E. Yorks.

We would welcome comments on this subject as there seems to be a need for better understanding of the position during the last years of the call-up.

VISITS

Visits have been arranged to Vickers-Armstrongs (Aircraft) Ltd., Weybridge, on Saturday morning 11th January 1958, and to the Guinness brewery at Park Royal, Middlesex, on Saturday morning 1st February 1958. Numbers are limited and as these are popular visits early application is advised to the Hon. Visits Secretary, Mr. R. Shepherd, 4 Heath Road, St. Albans, Herts.

LECTURE CANCELLATION

Owing to a last minute Air Ministry security veto the lecture by Mr. K. W. Clark on "The Background to Aircraft Specifications" which was to have been given on 7th November, had to be cancelled, and we must apologise to those who made the journey up to town in vain.

THE LIBRARY

Reviews

BEHAVIOUR OF METALS AT ELEVATED TEMPERATURES. *Institution of Metallurgists. Iliffe, London, 1957. 122 pp. Illustrated. 21s.*

Until recently, those concerned with power units were the only aeronautical engineers to be particularly interested in the high temperature properities of metals and alloys. Their interest continues, but the advent of much higher flying speeds has made the subject important also to airframe designers and to those responsible for the instrumentation of modern aircraft. Guided missiles and rockets present similar problems. Inevitably, the demands made by all these branches of aeronautics constitute a challenge to the alloy-makers, as neither pure nor nearly pure metals are of much value for high temperature service. That the challenge is being met may be gathered from this book. Complete answers to all the problems cannot yet—if ever—be expected but this little volume shows what progress has been made towards providing them.

The book consists of four papers, by different authors, given recently as a refresher course to the Institution of Metallurgists. Each paper is excellent in both content and presentation and contains far more detailed information than could be summarised here. Between them, the papers cover all the known materials likely to be useful in high temperature service, and they provide a great bulk of up-to-date data. One paper deals with the temperature range up to 450°C, naturally paying most attention to aluminium alloys but covering also titanium, magnesium and some steels. Another is devoted to non-ferrous materials for service above 500°C. It gives the expected prominence to nickel-based alloys but deals also with materials based on either cobalt, chromium or molybdenum; and it reviews the metals of the platinum group. The fourth paper is concerned solely with steels. Its author divides the useful ones into five groups and deals with the various factors affecting the high temperature properties of the members of each group.

These three papers are worthy of study by aeronautical engineers if only for the data they contain. But it may be that the first paper, by Dr. N. P. Allen, on "The Engineering Properties of Metals at High Temperatures," will interest them more. It is not lacking in valuable data but it deals more than the other papers with the deeper aspects of the subject, examining them in a way likely to win approval from the thoughtful. The author's treatment covers all metals and alloys and he uses any one he likes for illustrating his points. Though all four papers are of great value the first stands rather by itself because of its broad and philosophical approach to a very complex topic.—LESLIE AITCHISON.

MAGNESIUM CASTING TECHNOLOGY. *A. W. Brace and F. A. Allen. Chapman & Hall, London, 1957. 17 pp. Illustrated. 21s.*

To use a somewhat modified phrase of T. A. Rickard, one of the historians of metallurgy—"something like a million years have passed since the footfall of Man's on-coming could first be faintly heard along the corridors of Time." The natural resources available to this predestined pedestrian were then virtually as they are now. Yet, until less than 6,000 years ago, the metals, which have proved to be the mainstay of his material advance, were unknown to him. For countless ages until about the middle of the last century, Cortezlike, he could gaze across the sea little knowing that each cubic mile of its apparently unending waters contained almost five and a half million tons of magnesium. The metal, it is true was discovered a hundred and fifty years ago, but its fundamental chemistry and physics being what they are, Man's first metallurgical tools, the stone hammer and the open fire, were ill adapted for its winning, as indeed were also those available to him when it was first isolated.

During the lifetime of many, happily still with us, bulk electricity became available and thus the production of magnesium from sea or rock became a practical possibility. Due, however, to its chemical and physical characteristics, the metal and its alloys gave to their would-be founder novel and difficult problems, the solution of which has required both time and ingenuity. It is, therefore, only within a little more than the last generation that it has changed its main activity from sutteelike self-immolation at the instance of the pyrotechnist or the Press photographer, to being a valued engineering material.

In air, at a relatively low temperature magnesium develops on its surface a discontinuous and not too adherent oxide film and, at a little above its melting point, catches fire. While the metallurgist has coped, with a fair modicum of success, with the former difficulty, the founder has had to evolve an economic technique eliminating the latter risk. This last has, in the main, been done by developing fluxes having a melting point lower than that of the metal and a combination of physical properties giving rise, while it is in the furnace, to an oxygen impervious shield or cover.

To the engineer, it is the lightness of magnesium which is its initial attraction. To the founder, however, this quality is a serious disadvantage. With the engineering metals generally, the difference in density of flux or slag and molten metal is such that mutual entanglement does not often arise. With magnesium, however, this was initially difficult to prevent, but it can now be prevented. One method of achieving this, is to inspissate the flux (to use a word seldom employed from the time of Samuel Johnson until its resuscitation by contemporary magnesium technologists, or perhaps by their legal advisers?) This not too attractive word merely means to thicken. This is achieved by adding a substance to the flux (of which there are several), which so increases its viscosity as to make it virtually immobile.

During pouring, from pot to mould, the burning of the liquid stream has to be prevented. This can be done by surrounding it with a gaseous envelope of sulphur dioxide. Yet another foundryman's difficulty should be mentioned. Because the metal is so light (at pouring its density may not be in excess of 1·5) its pressure head will, from the foundry point of view, be exceptionally low, so very permeable sand must be used to allow the escape of air which might otherwise be trapped. Further, since in the mould the surface of the running metal would otherwise be in contact with air and moisture from the sand, the latter must itself contain one or more of such inhibitors as sulphur, boric acid, ammonium borofluoride and so on.

All these matters and many, many others relating to six classes of magnesium alloys and their properties (including their notch fatigue resistance), are described in this short

book by the late F. A. Allen and A. W. Brace. The work is well written, has a good bibliography and an index. Were it merely intended for foundrymen, one feels that some of its information, particularly three equilibrium diagrams, would be described by Hamlet, Prince of Denmark, as "caviare to the general"—what the foundryman might say, one hesitates to guess; but, pressed, one would probably guess right.—P. L. TEED.

THE GREAT DETERRENT. *Sir John Slessor. Cassell, London, 1957. 322 pp. 30s.*

Since the bomber took the place of the battle fleet, this country has lost the comfortable privilege described by Bacon as "to take as much or as little of the war as we will." The new situation has done nothing to remove the duty, as Sterne put it, of "keeping the ambitious and the turbulent within bounds." The burden of Sir John Slessor's book is that the emergence of nuclear weapons will keep them in bounds; that world-wide war has abolished itself; that the new weapons may well increase the number of local wars and that wise diplomacy and firm action must be applied in the danger spots; and that because of the new weapons the West can now have a real security which was impossible by any other means except at prohibitive cost.

If he could be proved right in the more important of those claims, the most sentimental among us would be obliged to withdraw demands, on the grounds of humanitarianism, for the forswearing of the nuclear weapons. His thesis has nothing to say to the moralists among us who hold that war is wrong and would have us consequently take no part in it no matter how "the ambitious and the turbulent" might make use of it to gain power and treasure. For the rest who hate war and yet have discovered no certain way of avoiding it, his arguments must have a seductive attraction. They are all based on his statement that it has never been any use trying to abolish any weapon of war and that the only hope is to abolish war itself. Although his opponents might object that certain weapons have remained unused in major wars even they would have to admit that they remained unused for fear of reprisal—that, in fact, the most horrible weapons were a deterrent against their use. Now, he says, the latest weapons are so dreadful that they have abolished major war itself.

To tie that claim to a forecast of more local wars, as he does, is a courageous acceptance of a likely result and yet, if anything, it strengthens his case by showing that he blinks none of the considerations. He holds that low-yield atomic bombs may have to be used in local wars. He is critical of the political inflexibility and lack of foresight that makes local wars probable in certain areas, of the influence of Aramco dollars as well as the termite policy of Russia in the Middle East and of the divergence of Commonwealth and American policy in the Far East. He is convinced that, in all those instances in which Britain has given pledges, she must honour them not only with air power but with military and naval power as well. He also advocates a more active policy among the N.A.T.O. Powers for taking the initiative in areas outside N.A.T.O. which are vital to the interests of those Powers.

He sees all the dangers and acknowledges all the weaknesses of the free world and he comes back to the conclusion of M. Spaak on the subject of stock-piling nuclear weapons. "One or other," wrote M. Spaak, "soon will have enough bombs at its disposal to strike an absolutely mortal blow at its opponent. Which of them has a surplus thus does not seem to me very important." And to that he links the remark of Sir Winston Churchill: "It is to the universality of potential destruction that we may look with hope and even with confidence." He goes on to say that the Kremlin must now know that any attack on a N.A.T.O. Power "would unleash total war." He adds that the enemy will be no more anxious to blow up a local war into a major war than we are. Of the possibility of a ruthless dictator arising and using the hydrogen bomb, his comment is: "Hitler might have launched the hydrogen bomb had he possessed it in the extremity of defeat and taken civilisation with him to his crazy Valhalla. I do not believe the Kremlin would run the risk—as a deliberate act of policy—chess is the Russian national game, not poker."

Over the years, all this has become familiar as the message Sir John Slessor had to deliver. This book brings together a score of his pronouncements on various aspects of this subject from 1948 onwards. It may therefore say nothing new; it may say the same things several times, but it is remarkable for its consistency and is thus a tribute to the soundness of the original thinking when all allowances have been made for the stubborn tenacity of the author. His reputation for hanging on to his conclusions through all opposition is reinforced by this book but the other part of his reputation for being able to make perceptive appreciations and to discern trends is also supported by several forecasts that have come true. For all its repetitions, this book inspires confidence. It makes no promise of an easy international epoch; it holds out no prospect of a cheap peace; but it may well be right in insisting that the big, utterly destructive war has been abolished by the evidence that it cannot be waged profitably or without mutual disaster.—E. COLSTON SHEPHERD.

SELECTED SPEECHES 1948-55. *H.R.H. The Prince Philip. Oxford University Press, 1957. 156 pp. 12s. 6d.*

This volume is in the Society Library largely because it contains our own British Commonwealth and Empire Lecture in December 1954. But even were it not, we should still have bought it, for one or other of the fifty speeches must interest our members. They have been chosen for their "diversity of subject and occasion" and there can be few men in history who have made so many speeches in so short a time on such a variety of occasions. What is more, none of them is in the slightest degree tedious, whether you are an expert in the subject being spoken about or have hardly heard of it. His Royal Highness has a style essentially his own and whether one has heard him in person or on the radio or television, nobody can say he is not worth listening to. By the same token the book is eminently readable.—F.H.S.

BOYS' BOOK OF FLIGHT. *David Le Roi. Iliffe, London, 1957. 180 pp. Illustrated. 12s. 6d.*

With a nice sense of opportunism, Iliffe's have produced this book in time for the Christmas market. David Le Roi is the name of the author but there is a subtitle "in association with the Staff of *Flight*" and since many fathers read that Journal regularly they will know that the book has an authoritative and experienced backing. The illustrations are excellent—both photographs and diagrams—and the latter include ten of the famous *Flight* cutaways. There is a bit of everything (except history) but if the publishers really wanted to be on the ball they would have slipped in an addendum on the Sputnik.—F.H.S.

MODERN AIRMANSHIP. *Edited by Col. Van Sickle. Van Nostrand Co. Inc. & MacMillan Ltd, 1957. 862 pp. Illustrated. 70s.*

This claims to be a "comprehensive, authoritative book on all the basic aspects of modern flying."

The editor of an encyclopaedia needs very special qualities—he must himself have a wide knowledge to enable him to choose specialist writers who really know, and can expound, their subject. Secondly, he must insist on a well-balanced presentation. It is an old joke in aeronautics that every specialist regards his own part of the aeroplane as vital; the rest ancillary: the undercarriage designer sees the wings as a support for the wheels. The editor of an aeronautical encyclopaedia must control such specialists. It seems to me that Colonel Van Sickle has failed both to secure contributors who are all adequately qualified and to control the length and character of their contributions.

Chapter III covers both subsonic and supersonic aerodynamics in 35 pages. The standard is poor. The descriptions of induced drag (p. 53) and stability (p. 64) are only two of many which are nonsense. The only importance of aspect ratio suggested is that "the higher the aspect ratio, the closer the approach to elliptic pressure distribution." Valuable space is taken up with statements such as "Weight always acts along the gravitational axis." The latter is not defined but is presumably the direction in which weight always acts.

Chapter IV on Structures describes controls and flaps all over again and rather better than Chapter III. Unfortunately the author starts his section on "Stresses and Strains" with "The weight of the aeroplane, acting from its centre of gravity, is held aloft in flight by the lift of the wings," and goes on to define external forces on a body as "loads" and internal forces as "stresses."

The section on helicopters begins with an interesting, illustrated historical survey but soon contains "Ground cushion is a volume of packed air. . . ." "The packed air is denser thus increasing the efficiency of both the engine and the rotor system." These examples of inaccurate statements are unfortunately only a few of the dozens in the book.

The second task of the editor, to hold a balance, is a difficult one. The reader is himself probably biased, but who will defend Aerodynamics being given 35 pages while Instrument Procedures for pilots are given 80? Most of the contributors are members of the United States Air Force and the meteorological flight procedures referred to are American and not necessarily international.

Another unevenness is in the standard of knowledge assumed. On one page is an elementary diagram of the working of a piston engine of the kind contained in many boys' books while, only a few pages later, is a formula for lift coefficient in supersonic flight.

The book is well illustrated and naturally leans heavily on photographs, diagrams and descriptions provided by manufacturers. In fact, these contributions are the best part of the book. "Modern Airmanship" is well printed on good paper and weighs about 3 lb. It is a pity that so much time and money went in the production of so unsatisfactory a book.—A. H. YATES.

INTO THE SILK. *I. Mackersey. Robert Hale, London, 1957. 239 pp. Illustrated. 16s.*

This most interesting book by Ian Mackersey is really a history of the Caterpillar Club, which means to say it is partly a biography of Leslie Irvin and partly a catalogue of miraculous and astonishing escapes by parachute, with or without the aid of ejector seats. It describes much of Irvin's early work in the development of parachutes in the United States and it gives something of the development of the ejector seats by Jimmy Martin and the early difficulties associated with them in this country.

Leslie Irvin is a very unusual man and the story of his achievements is perhaps more unusual still; one would have liked the author to have gone more deeply into that side of the story. However, a very large selection of detailed and vivid accounts of the adventures of various air crew who saved their lives by parachute is no less interesting. Most of the accounts are so extraordinary and there are so many of them, that by the time one is half way through this book one tends to lose one's sense of proportion and to accept the bizarre, the incredible, the million-to-one chance, as normal. Your reviewer owes his life to an Irvin parachute but was fortunate in having an easy escape, a warm and pleasant journey earthwards, and a soft landing followed by a most friendly reception by the locals. But after putting down "Into the Silk" he had the feeling that he had somehow got into the Caterpillar Club by false pretences or at least the easy way.

No doubt if Leslie Irvin had never been born the parachute as we know it today would still have been developed. Its early history, however, might have been very different, for without Irvin's drive and faith and singleness of purpose the free-falling parachute as a device for saving the lives of air crew might have got away to a very much slower, and more confused, start. This is very apparent from reading the early part of this book so, although very many thousands of aviators now owe their lives in a sense to Leslie Irvin, it is the early "Caterpillars" who really stand in his debt.

When the last page of "Into the Silk" is reached the over-riding thought in one's mind is how very worthwhile the whole thing was. Leslie Irvin with his parachutes, and later Jimmy Martin with his ejector seats, can see around them the results of their efforts in the form of human beings alive and well, but who would otherwise be dead.—J.K.Q.

R.A.F. BIGGIN HILL. *Graham Wallace. Putnam, London, 1957. 288 pp. Illustrated. 21s.*

Published on the seventeenth anniversary of the Battle of Britain this is a most interesting and authentic account of Biggin Hill's very considerable part in this vital series of events in the history of the British Empire.

Graham Wallace paints a ring-side picture of unquestionable accuracy of the battles which were fought over, round, by, with and from Biggin Hill. Indeed with respect to the other stations in 11 Group and other Groups in Fighter Command the very name Biggin Hill epitomises the Battle itself. The downright hard work (with precious little glamour) of those hectic and tragic months is sometimes forgotten by a short-memoried public.

This book is not all blood and thunder. It is the result of what must have been a tremendous amount of interesting research for the author since it tells of how the station was opened in January 1917 as the Wireless Testing Park some time before it become a fighter station. Biggin Hill was the centre of the earliest experiments in air-to-air and air-to-ground Radio Telephony. Much of the story will be unfamiliar even to students of the history of the R.A.F. The author tells of how night fighters sought Gothas and Zeppelins by night and more Gothas by day from this aerodrome on the North Downs. Biggin Hill was, in that earlier war, as in the Second World War, a key station in the defence of London.

The stories of the Squadrons and their pilots during

their periods of residence at this most famous of all fighter stations range from 1917-1957, forty momentous years. The greater part of the book tells of the slow build-up of activity to the Battle of Britain and the subsequent gradual decline of activity following the invasion of France in 1944 and ends with a brief reference to the solitary Hunter Squadron based there today.

The narrative is highly stimulating and the verbatim combat reports and R/T conversations are uninhibited in the extreme and give an authentic atmosphere to the story.

So many squadrons lost their day-to-day records, due to their endless movements from station to station, that it is fortunate for some of them that Biggin Hill was so well served by its Intelligence Officers, since the records are very complete during the difficult period of the first three years of the War. Graham Wallace has brought to life the famous and the less distinguished, "Stuffy" and Sholto, Malan and Tuck and, perhaps best of all, he gives the reader a most inspiring picture of the W.A.A.F.'s under fire, shaken but determined, battered but undaunted. The thought of a W.A.A.F. N.C.O. picking her way among delayed action bombs on the aerodrome, marking their positions with red flags, even as, occasionally, one exploded nearby, may be unfamiliar to some readers, but this very act won a Military Medal. Altogether, six M.M.'s were awarded the Women's Auxiliary Air Force and Biggin Hill W.A.A.F.'s won three of them.

This book is remarkable for its accuracy, but is rather marred by the dust jacket which shows three Spitfires taking off, all three with full flap—an unprofitable thing to do. The book is, however, a fitting tribute to the station whose pilots shot down over one thousand enemy aircraft. The "most bombed station in fighter command" has a very proud boast which it shares with a certain London Theatre—"we never closed."—A.S.C.L.

THE MILLIONTH CHANCE. *James Leasor. Hamish Hamilton, London, 1957. 176 pp. Illustrated. 18s.*

There seems to have been a spate recently of renewed interest in the history of the airship. Regrettably, the attention given to the subject has not been as well-informed as one could wish. There has been an undue emphasis on the tragic and spectacular aspects of the story.

Mr. James Leasor confines himself to one small part of the history of lighter-than-air craft but it is a part which was of the greatest significance in the development of air transport and—being well written—his book is one which everybody interested in the history of British Aviation will find worth reading. The informed reader may, however, be irritated in places by certain obvious inaccuracies and by a lack of selectivity and balance in the use made of some of the material which has been so painstakingly unearthed. Nevertheless, the account gives almost all the more relevant facts of a complicated and fascinating story and presents them in a highly readable form.

The result is a strangely gripping biography of an airship, the great British rigid R.101. It is a sad tale of a noble—if misguided—concept; of over-ambitious policy-making and of the inevitable watering-down of the programme which always follows; of a plan of action which gave away too much for the sake of the usual political compromise; of over-long development times from attempting too much and because of a parsimonious Treasury; of the meddling of politicians in a technical field which they could not be expected to understand; of the all-too-human individual traits of jealousy, stiff-necked pride and doctrinaire narrow-mindedness, founded on the recurring theme of State versus private enterprise; and, in the end, of the seemingly inevitable consequences, when Fate finally intervenes in terrible fashion.

Nevil Shute and others have already pointed out the parallels between the R.101 and other more recent civil and military air projects. It is these similarities which give this story a special significance, both for the present and for the future. This is a fragment of air history which needed retelling, not so much to remind us of those fantastic extinct vehicles (dimensionally as large as an ocean liner) which, as a quite distinct method of transport, had a complete span of existence—from the first realisation to final oblivion—of only forty years, but, much more importantly, to point a moral for our own times.—P. W. BROOKS.

THE SHIP BUSTERS. *Ralph Barker. Chatto and Windus, London, 1957. 272 pp. Illustrated. 16s. net.*

The story of the Beaufort torpedo bomber squadrons of the R.A.F. has not been told adequately before but Ralph Barker makes good the omission very well.

To deliver a torpedo has always required steady nerves because the pilot has to fly steadily and fairly slowly, low over the water, to within half-a-mile of the target before releasing the missile to have the slightest hope of scoring a hit. This also means flying straight towards a tremendous concentration of anti-aircraft guns and finally over the target itself at mast-head height.

Such are the demands of torpedo dropping that they breed a very fine type of leader. Perhaps the greatest torpedo pilot in the R.A.F.—a fanatic in some respects—was Pat Gibbs. The stories of his exploits and those of his colleagues in Nos. 22, 42 and the few other Beaufort torpedo squadrons, firstly in the North Sea and the English Channel and later in the Mediterranean are very well told. Due credit is given to the six gallant Swordfish crews of 825 (Fleet Air Arm) Squadron led by Lieutenant Commander Esmonde whose daring prelude to the main R.A.F. torpedo strikes against the *Scharnhorst, Gneisenau* and *Prinz Eugen* ended so tragically when the German ships made their spectacular dash up-channel in February 1942.

Whether or not the tremendous effort and excessive loss in aircraft and crews required to score a single kill were justified is left open to doubt. Although the author himself served on torpedo operations and might be expected to be biased, he has successfully avoided appearing to be so. He has even avoided expressing his own opinion about the seeming inefficiency and lack of staff work in preparing the Beaufort crews for the vital attack on the three German ships.

Barker reminds the reader of the important and successful work of Mediterranean-based Beaufort crews in denying Rommel the petrol he desperately needed at the time of the 8th Army's offensive at El Alamein.

The author's style permits a vivid description of the events, although once or twice he has tended to slip a little tediously into the documentary realm. Barker is an author who has exceptional powers in holding the reader's attention and there were occasions when it was hard to put the book down. Another excellent feature of the book is the inclusion of a really useful index.

Documentary or dramatic, whichever way this book is read its impact is sharp—a reminder of the demand for a cool brain and guts and the application of carefully studied peace-time theoretical training to the demands of war. The torpedo pilots of the R.A.F. suffered many baffling failures but were sometimes rewarded with staggering success.—A.S.C.L.

AIRPOWER; THE DECISIVE FORCE IN KOREA. *Editor James T. Stewart. Princeton, N.J. D. van Nostrand (London, Macmillan), 1957. 310 pp. Illustrated. 45s.*

This book is composed of a collection of papers, each dealing with a separate aspect of the war in Korea from 1950 onwards. From the point of view of the student of military history they can be regarded as making a contribution to thought. Some of the statistics, particularly the claims of ground transport destroyed by aircraft, should I think be regarded as suspect. After reading these papers my vocabulary was enlarged. I was particularly charmed by the verb "to attrite"—derived from the word "attrition" no doubt. I have never met it before.—P. B. JOUBERT.

MEN WITH WINGS. *Wing Commander "Sandy" Powell. Allan Wingate, London, 1957. 169 pp. Illustrated. 15s.*

Far too little is known about British test pilots for many of them have had experiences which are well worth putting on record. This is shown by Wing Commander Powell in his latest book. It is unfortunate, however, that "Men with Wings" cannot be given unqualified praise. The author tells a good tale but, frankly, his choice of subjects is not easy to follow.

The careers of seven test pilots are described—significantly, not the names known to everyone but those whose work has been every bit as valuable as that of their more glamourised colleagues, if a little less spectacular. He also includes the story of the work of the famous Fred Rowarth. This story should be better known than it is by post-war enthusiasts, but he seems to be rather out of his rightful place in such company.

Despite Powell's undoubted ability as a story-teller, his style is a little tiresome and his personal reminiscences might have been left out altogether. He tells one very dramatic story twice, consecutively, the first time as told to him by the person concerned and immediately afterwards in the words of the official report on the incident. The whole dramatic effect of the story is thus lost. In another instance, a full test report on a new aircraft is given. One cannot help wondering what sort of people the author had in mind when he composed the book. The technician might be interested in the flight test report, control loads, flight speeds and all the other figures quoted but perhaps not in the rest of the book. The young enthusiast probably would not be so interested in these details nor is he likely to appreciate many of the references to the pre-war R.A.F. which seem to presume personal knowledge on the part of the reader.

The use of the present tense is something which, in a historical narrative can be dangerously misleading. For example, Powell states that Air Marshal Sir Richard Atcherley is "now" C.-in-C. Training Command. Such a posting is unlikely to be for an indefinite period (fortunately for Sir Richard).

As in his previous book, Powell has allowed far too many mistakes to occur. Most of them are in proof reading, but some are errors of fact and all are avoidable. These mistakes, coupled with a muddled approach to the subject give an impression of undue haste and rather spoil an otherwise interesting book.—A.S.C.L.

BEST FOOT FORWARD. *The Autobiography of Colin Hodgkinson. Odhams, London, 1957. 255 pp. Illustrated. 18s.*

This is a striking book. In 1938 Colin Hodgkinson was learning to fly in the Fleet Air Arm and on an instrument training flight in a Tiger Moth "under the hood," he was in collision with another aeroplane which was on a similar exercise. In the resulting crash, he lost his right leg. His left leg was also badly damaged and, when it showed no signs of recovering, he volunteered to have it removed as well, and so launched himself upon a remarkable journey.

"Best Foot Forward" is the autobiography of a man who has demonstrated courage and determination of the highest order. The book is not for the squeamish for the author spares the feelings neither of himself nor of his reader. It is a very honest and forthright confession of human weakness in which Hodgkinson reveals the humiliation of the athlete who loses his legs and, apparently, all possibility of living the active, thrusting life developing in a young man of twenty.

Quickly and with the bounding resilience of the games player brought up in the tradition that the sport is the thing that matters and one's hurt is incidental, he challenges his disability, hurls away his sticks and stumps his cheerful, if arrogant, way back to flying, supported by two of Roehampton's famous tin legs.

Hodgkinson achieves two of his greatest ambitions by conquering his fear of flying and by badgering the authorities into letting him fly Spitfires on operations. Much of the inspiration which culminated in these achievements was due to the success, in similar circumstances, of Douglas Bader. The Foreword by the great Sir "Archie" McIndoe, the patcher of broken and burnt faces and limbs is a well deserved tribute to the author's courage and determination.

It would be unworthy and unjust for anyone, who has not had to endure one-tenth part of what "Hoppy" Hodgkinson suffered, to make thoughtless criticism of this book. Nevertheless, criticism there must be for, probably quite unconsciously, he has failed to do himself justice in his remarkably materialistic approach to his experiences. One cannot help, occasionally, being driven to the conclusion that the book is written by an egocentric with no finer feelings than self-justification at any price, no matter who suffers—with the notable exception of his mother.

There is something rather disturbing about his lack of realism. He seems to lay far too much stress on the physical problem, the determination to overcome it and the ultimate, triumphant success. The driving spirit, the motive, the deeper desire for something greater and more satisfying than self has been left out almost entirely. Yet—it was there. What a pity it was played *pianissimo* as if from a sense of shame. What might have become a classic autobiography has emerged with a rather threadbare look but it is still a very remarkable tale.—A.S.C.L.

1. A.G.A.R.D. FLIGHT TEST MANUAL. *Volume IV. Instrumentation Systems. C. D. Perkins and E. J. Durbin, A.G.A.R.D., Paris, 1957. Loose leaf. Illustrated.*

2. INSTRUMENTATION IN TESTING AIRCRAFT. *C. N. Jaques. Chapman & Hall, London, 1957. 291 pp. Illustrated. 45s.*

The use of instrumentation in flight testing of aircraft has grown so rapidly during the past 20 years that it now almost seems to represent a controlling factor on the types of flight test which are practicable whereas it should be, of course, regarded as an aid to the production of the required result and an improvement in efficiency. The modern flight test engineer must therefore devote considerable effort to becoming acquainted with the science of instrumentation, since it is often not included in his basic training. Only by obtaining a complete understanding of the *modus operandi* of instrumentation systems can he

select the most appropriate system for any particular investigation. In view of this situation, it is somewhat surprising that there have been so few publications devoted to modern flight test instrumentation. The reason for this may lie in the rapid growth of the subject, so that there are relatively few authors competent to treat it comprehensively. Furthermore, any published work may be obsolescent before it is printed.

The two publications reviewed here represent, in their separate ways, the first serious attempt to present in co-ordinated form a picture of the instrumentation systems available to the modern flight test engineer. The first of these comprises Volume IV of the A.G.A.R.D. Flight Test Manual. A.G.A.R.D. was formed under the auspices of the North Atlantic Treaty Organisation to co-ordinate information of use to aeronautical scientists in the various countries belonging to the organisation and commendably accepted the task of publishing concerted works on specific subjects. Volumes I and II cover performance and stability and control, respectively, whereas Volume III comprises an instrumentation catalogue. This latter volume, as the title implies, is a very comprehensive list of the types of instrument available but makes no attempt to treat the subject of instrumentation as the genuine branch of aeronautical science which it has become. Volume IV, entitled "Instrumentation Systems," rectifies this deficiency in a very comprehensive manner. In common with the previous volumes, it is the combined work of a number of specialist authors. Broadly speaking, it accepts that the instrumentation used on any particular aircraft may be considered as a system, the basic function of which is to collect required data in a form most suitable for analysis, paying due regard to the type of problem under investigation.

The volume is divided into three parts, the first of which introduces the idea of instrumentation systems and discusses the factors governing the choice of any particular system. Part 2 represents the majority of the volume and is entitled "Data Collection." Recording and measurement techniques are included. This part will probably be the most widely useful to the flight test engineer who wishes to inform himself concerning any particular type of measurements of recording gear. The early chapters, dealing with the fundamental characteristics of measurement and the dynamic response of instrument systems, are extremely valuable since it is essential to understand the limitations inherent in any type of measurement before it is possible to assess the reliance which may be placed on the ultimate answer. In addition to this there are sections dealing with the measurement of displacement, temperature, pressure, vibration and acceleration, force and strain, fluid flow and air flow, and these appear to cover all the systems in common use both in this country and in the U.S.A. In addition, there is a descriptive section devoted to telemetry systems which forms a useful background to the subject and it is interesting that the author of this section has quoted the approximate cost of various systems. Part 3 is devoted to data reduction systems and, again, this part is of a general nature. Clearly, in a volume of this type, it would be impractical to digress into the details of the various component parts of a data reduction system but the information given does serve as a useful over-all survey of present ideas.

The use of this volume is two-fold. In the first place, it presents, in unified form, a very comprehensive description of the instruments and instrumentation systems in common use at the present time. This provides a useful source of reference to the practical flight test or instrumentation engineer. Secondly, however, an endeavour has been made to point the lines along which development work is proceeding. Since the volume is produced in loose-leaf form, common to the previous three volumes in this series, it is hoped that it will be found possible to keep it up to date by the issue of publications concerning these developments as they take place. The whole volume represents an extremely useful addition to the series and has been presented with the same thoroughness as the previous three volumes. It will be indispensable to any organisation concerned with the flight testing of aircraft.

The second publication, entitled "Instrumentation in Testing Aircraft" has been written by C. N. Jaques and is published as a monograph under the authority of the Royal Aeronautical Society. It is a useful coincidence that this book has appeared at the same time as the previous one, since, in many ways, it supplements the A.G.A.R.D. Manual while the general pattern is extremely similar. It has been stated that the author's primary aim is that the reader should quickly be able to find answers to the questions:—

(*a*) what generally applicable methods of recording data are available?

(*b*) what are the proven ways of measuring a particular physical quantity?

These are the questions, of course, which are paramount in the mind of the engineer planning any flight experiment.

Part 1 is devoted to basic principles and includes discussions of the dynamic response of instruments as well as some fundamental transmission systems. A thorough study of this part will be invaluable to the understanding of the limitations of instrumentation and the subject matter is well presented. Part 2 is devoted to the measurement of physical quantities and it is interesting to note the inclusion of a discussion on noise measurement in this part. The measurement of noise is becoming one of the most popular problems of the present day, and yet it is often overlooked. Part 3 is devoted to data transmission and recording and describes in some detail many of the recorders in present use in this country but is largely restricted to conventional methods of recording, *i.e.* oscillograph recording or photographic observers. There is no attempt to predict the future by any reference to magnetic tape or more sophisticated recording media.

As might be expected, the contents of this monograph are restricted almost entirely to instrumentation of British origin. The general presentation is excellent. To the student it presents an extremely valuable text book and to the flight test engineer it will form a useful concise reference work.—C. F. BETHWAITE.

AN INTRODUCTION TO AUTOMATIC DIGITAL COMPUTERS. *R. K. Livesley. Cambridge University Press, 1957. 53 pp. Illustrated. 8s. 6d.*

The vast majority of books on Automatic Digital Computation published so far have been of a specialist nature and demand a thorough and painstaking reading before the basic principles can be absorbed. Many people, however, are not sufficiently concerned with actual computer use and operation to warrant such a reading and their interest terminates with an idea of the broad operating principles. For such people this is an excellent book written in a concise and readable form and will prove invaluable for the engineer whose object is to gain a user's knowledge of automatic computers, as opposed to the specialist knowledge which is already well catered for in published literature.

The book assumes a knowledge of simple algebra and

very little else and starts off with a solution of a set of simultaneous linear algebraic equations by successive approximations. This is taken as an example and the detailed steps in reaching a solution are shown to reduce to a series of simple operations which could be carried out by a person with only the facility for doing simple arithmetic. It is shown that even such instructions are much too complicated for an automatic computer and, to fix the ideas of the reader, a simple imaginary computer using a numerical instruction code is described and illustrated, and a programme to carry out the example is written. Initially instructions are fed in through the input in the order in which they are obeyed, and subsequently a control unit is described which enables the computer to obey instructions already held in the computer. Instruction modification is also discussed and the major aspects of machine programming covered, so that useful and instructive exercises could be done on this imaginary computer.

The second chapter is devoted to a discussion of input, storage and output of numbers and a broad description is given of various systems covering current practice on British computers. The third chapter discusses the organisation of programmes describing how basic pieces of programme (called sub-routines) can be called upon in the execution of a major programme and how these sub-routines play a major part in the preparation of a given job for machine computation. As might be expected in a a book by an experienced programmer, some stress is laid on the fact that very few programmes work correctly the first time, and a discussion of some common faults is given. Automatic programming gains cursory mention and it could be argued that in a book of this type, aimed at a popular appeal, more space might be devoted to it.

The final object of a digital computer is to solve engineering problems and a chapter is devoted to indicating how this comes about both for "one off" and repetitive problems. Specific types of problems are discussed, but these must be looked upon as examples rather than an attempt to cover the field of possible applications.

At first sight one is apt to criticise the production of little more than 15,000 words in book form, with the attendant cost, and the private buyer could not be criticised for doubting the advisability of paying eight shillings and sixpence for a few hours reading. However, the book is of a high standard and can be recommended as a concise and well written introduction to the subjects of operation and use of an automatic digital computer.—J. J. FOODY.

MATHEMATICS AND COMPUTERS. *G. R. Stibitz and J. A. Larrivee. McGraw-Hill, New York, 1597. 228 pp. Illustrated. 37s. 6d.*

The past decade has seen the appearance of high speed electronic computers and their use in a widening variety of fields—engineering, aircraft design, operational research, language translation and clerical mechanisation. The authors of this book have produced an excellent elementary introduction to computers in general, how they operate and why they are needed.

The early chapters describe the kinds of computing problems which arise and their origin: typical paragraph headings include "Almost everyone uses differential equations" and "Statistics—sifting the haystack for the needle."

The history of computers from the abacus (600 B.C.) onwards serves to provide a background for chapters on the logical design and components of high speed computers. The use of the binary scale of notation is given particular attention and binary addition is demonstrated by analogy with the familiar landing light with two switches.

The section on Numerical Analysis begins with a warning about the introduction of errors in computation and also gives elementary examples of typical problems in numerical methods such as the determination of the roots of a polynomial. The propagation of errors by the machine itself is also briefly described.

In discussing analogue computers and simulators, mention is made not only of the familiar differential analyser but also of such simple devices as the hydraulic equation solver of Demanet which finds the roots of certain types of cubic equations. A further chapter deals with the use in computing of random numbers and the so-called Monte Carlo methods. For one of the examples given (solution of simultaneous equations) it should be stressed that more powerful methods exist. Finally, examples are given of computers at work (and play) followed by a selected bibliography.

One book is quite insufficient to deal adequately with such a large subject, but the authors have produced a readable introduction which should arouse further interest in even the most general reader.—T. VICKERS.

PRINCIPLES OF TURBOMACHINERY. *D. G. Shepherd. Macmillan, New York, 1956. 436 pp. Diagrams. 56s.*

Professor Shepherd is already well-known as a member of the original Power Jets team, and as the author of a widely-used introductory book on gas turbines. In the volume under review, he sets out to provide a unified presentation of the thermodynamic, gas dynamic and/or hydraulic principles underlying the design of the various forms of turbomachine-compressors, pumps and turbines of radial or axial flow layout, using water, steam, air or combustion gas as working medium. This is in itself an ambitious but long overdue programme, so that the author has wisely refrained from discussion of questions of mechanical design, except in so far as they limit the attainment of design objectives. As he states in the preface, these are matters in themselves needing a unified treatment which would involve consideration of many types of machine besides those strictly encompassed by the title.

Inevitably, such a wide field, including as it does work drawn from many branches of engineering over a long period of time, is very far from possessing a unified basis in terminology, in symbols or in the coefficients and non-dimensional parameters employed, so that Professor Shepherd is faced at once with a dilemma: is he to introduce a unified terminology, and so on, which, while consistent, is bound to be at variance in detail with most if not all of current practice, or is he to use the "language" appropriate to each "region" and thereby to some extent to fail to achieve the unity he is seeking. Whichever the solution adopted—and in fact both are used—there is bound to be disagreement, but that is insufficient reason for not making the attempt.

In the event, an eminently sensible course is adopted. In the first five chapters, dealing with the principles common to all turbo machines, a consistent terminology is indeed used, while in the six chapters that follow, which cover the special requirements of the various types of machine individually, each is treated in a manner appropriate to the general practice for that type. Even here there is difficulty, for the British, American and German approaches to axial compressor design, for instance, are different in detail, and have perforce to be treated as such.

Referring briefly to the mode of treatment, we have

first a short introductory chapter showing photographs of the main classes of component to be described, followed by a very necessary chapter on units, dimensions and dimensional analysis, not forgetting to emphasise the physical interpretation and practical application of the various non-dimensional groupings. A chapter on energy transfer between fluid and rotor surveys very adequately the bedrock of the whole subject, dealing also with the question of reaction in its various definitions.

A chapter on thermodynamics presents the essential data in this field required for later developments, covering such questions as nozzle flow, shock waves, efficiency, reheat factor and the use of gas tables. The last of the general chapters then describes practical flow processes in machines, with emphasis on duct losses, boundary layer effects, cavitation, three-dimensional effects and losses.

Chapters are devoted successively to Centrifugal Pumps and Compressors (including mixed or diagonal flow machines), Radial Flow Turbines, Axial Flow Turbines, Turbine Performance and Comparison, Axial Flow Compressors and Pumps, and Compressor Performance and Comparison. In all these chapters a wealth of useful information is presented, supplemented by extensive references. Naturally no one type is treated as exhaustively as it would be in a text devoted to it, but since the author's aim is not to provide detailed design data, his coverage and balance of material is admirable.

The whole book is very well illustrated and printed, making it somewhat expensive, but a very good buy for student and practising engineer alike.—J. R. PALMER.

AIR DATES. *Air Commodore L. G. S. Payne. Heinemann, London, 1957. 565 pp. 42s.*

The dust cover of this book describes it as a "chronological survey of the principal events in the fields of military and civil aviation in Great Britain and abroad, beginning in 1783 with balloon ascents in Paris, and ending on 31st December 1956." Such a claim makes it sound like the sort of volume that should cut this reviewer's work by about 25 per cent, occupied as he is with time-absorbing inquiries as to who was the first to do this and that in an aeroplane, glider or balloon and when. Alas for such hopes. I suppose "principal" is the operative word and what may be important in one person's eyes is of no importance in another's. For example, Pegoud finds no place in the Index while Hitler has 18, only about two of which have any bearing on the air. The devotion of only 81 pages to history up to 1939 and the remainder of the book to subsequent events strikes one as being a little top-heavy. Despite these criticisms there can be little doubt that the chronology will be useful as a reference tool and any apparent prejudice may be due to the fact that there is only one reference to the publishers of this journal—to its foundation, in fact, when it was *not* "British" Royal Aeronautical Society but was the Aeronautical Society of Great Britain.—F.H.S.

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21st-22nd OCTOBER 1957

753 Global Navigation in High Speed Aircraft. Keith R. Greenaway.
754 Gas Turbine Combustion System Design. F. D. M. Williams.
755 Simulated Flight Training—Its Uses and Limitations. G. B. Lothian.
756 When Is an Aircraft a "Nuisance" in the Eyes of the Law? A. R. Paterson.
757 Flying the Jet Stream. P. R. J. Reynolds and C. L. Chandler.
758 Jet Weather. P. D. McTaggart-Cowan.
759 Exit and Re-entry Problems. G. V. Bull *et al.*
760 Standby Rocket Engines for Civil Aircraft. G. E. Rice.
761 Scheduled Helicopters—The Year 1960. R. L. Cummings.
762 Recent Advances in the Aerodynamic Design of Axial Turbomachinery. W. H. Robbins and H. W. Plohr.
763 Stability and Control Characteristics of the Vertical Attitude VTOL Aircraft. E. R. Hinz.

Reports

AERODYNAMICS

BOUNDARY LAYER—*see* FLUID DYNAMICS AND THERMO-AERODYNAMICS

COMPRESSIBLE FLOW—*see also* TESTING AND INSTRUMENTS

The minimization of wave drag for wings and bodies with given base area or volume. M. A. Heaslet. N.A.C.A. T.N. 3289. *July* 1957.

The minimisation of wave drag for thin aerodynamic shapes carrying no lift is studied for conditions under which either base area or volume is specified. The problem is reduced to one of determining a two-dimensional harmonic function with known boundary conditions. In several examples the theory is applied to the calculation of the minimum drag and to the final determination of the body shape.—(1.2.3.1 × 1.10.1.2).

Experimental investigation of attenuation of strong shock waves in a shock tube with hydrogen and helium as driver gases. J. J. Jones. N.A.C.A. T.N. 4072. *July* 1957.

An experimental investigation has been made of the attenuation of strong shock waves in air in a shock tube. Time-history measurements were made of the static pressure at several stations in the wall of the tube. The internal diameter of the tube is 3·75 in. Shock-wave-velocity data were taken for a distance along the tube of about 120 ft. The range of the shock-wave Mach number covered was from 5 to 10½ and the initial pressure ahead of the shock wave varied from 5 to 100 mms. of mercury. Hydrogen and helium were used as driver gases.—(1.2.3.2 × 1.12.1.3).

CONTROL SURFACES—*see also* WINGS AND AEROFOILS

*An experimental introduction to the jet flap. N. A. Dimmock. C.P.*344. 1957.

The experimental results obtained with two two-dimensional aerofoils, each having a 12·5 per cent thick elliptical cross section with a narrow full span jet slot at the trailing edge, the jet deflections being respectively 90° and 31·4° are recorded. The losses in the system have been considered and some of them investigated, those due to Reynolds number and jet entrainment effects being included. Also, the influence of ground proximity on the lift and centre of lift of the 31·4° model was measured at zero incidence. A tentative empirical expression is suggested for the pitching moment coefficient.—(1.3.4).

Estimation of incremental pitching moments due to trailing-edge flaps on swept and triangular wings. H. A. James and L. W. Hunton. N.A.C.A. T.N. 4040. *July* 1957.

A method is shown by which the incremental pitching moment of swept and triangular wings due to flaps at low speeds can be estimated by using two-dimensional data in conjunction with span-loading theory. Some two-dimensional flap parameters pertinent to the application of the method are summarised in graphical form—(1.3.4).

The subsonic static aerodynamic characteristics of an airplane model having a triangular wing of aspect ratio 3. *III—Effects of trailing-edge flaps. B. E. Tinling and A. V. Karpen. N.A.C.A. T.N.* 4043. *July* 1957.

Wind tunnel tests were conducted to find the effects of single-slotted flaps on the longitudinal stability at low speed, the rolling effectiveness of trailing-edge ailerons and of differential deflection of the horizontal tail when the flaps were deflected 40°, and the effect of small deflections of the flaps on the lift-drag ratio at Mach numbers up to 0·95.—(1.3.4 × 1.8.2).

FLUID DYNAMICS

*The motion of slightly viscous fluid between two non-coaxial rotating cylinders. W. W. Wood. A.R.L. Report A.*103. *April* 1957.

The motion of viscous fluid between two rotating, circular cylinders whose axes are set slightly apart is analysed by a perturbation method. The perturbation expansions appear to converge uniformly for all values of the fluid viscosity. The solution is used to illustrate the behaviour of the higher order corrections to boundary layer theory.—(1.4 × 1.1).

INTERNAL FLOW—*see also* POWER PLANTS

*On the tilting of nozzle liners. T. A. d'Ews Thomson and R. E. Meyer. A.R.L. Report A.*100. *January* 1957.—(1.5.1.4).

An investigation of discharge and thrust characteristics of flapped outlets for stream Mach numbers from 0·40 *to* 1·30. *A. R. Vick. N.A.C.A. T.N.* 4007. *July* 1957.

Discharge and force characteristics of flapped outlets, rectangular in cross section, have been determined. The basic outlet configuration was unchanged, and different flaps were attached to the outlet. Results are presented in the form of design charts for such variables as outlet discharge-flow ratio, flap angle, flap hinge-point location, and flap aspect ratio. Also presented are the variations of outlet duct pressure at a zero discharge rate for different flap angles and aspect ratios.—(1.5.1).

LOADS

Loads on a model during starting and stopping of an intermittent supersonic wind tunnel. K. G. Winter and C. S. Brown. AGARD Report 65. *August* 1956.

Measurements are given of the loads on a model during starting and stopping of an intermittent supersonic wind tunnel at Mach numbers of 2·00 and 2·48. Qualitative agreement is obtained with a simple theory but a need is evident for further measurement at higher Mach numbers. The use of a model loading coefficient in terms of tunnel stagnation pressure is proposed.—(1.6.3 × 1.12.1.3).

STABILITY AND CONTROL—*see also* CONTROL SURFACES AND WINGS AND AEROFOILS

The subsonic static aerodynamic characteristics of an airplane model having a triangular wing of aspect ratio 3. *I—Effects of horizontal-tail location and size on the longitudinal characteristics. B. E. Tinling and A. E. Lopez. N.A.C.A. T.N.* 4041. *July* 1957.

The model was tested with horizontal tails, which had areas of either 16·7 or 21·9 per cent of the wing area, placed −0·10, 0, 0·10, or 0·20 wing semi-span above the wing chord plane, and either 1·2 or 1·5 mean aerodynamic chord behind the moment centre. The horizontal tails had aspect ratios of 4 and no sweep back of the 50 per cent chord lines. The tests were conducted at a Reynolds number of 2·5 million at Mach numbers from 0·25 to 0·95.—(1.8.2 × 1.10.2.2).

The subsonic static aerodynamic characteristics of an airplane model having a triangular wing of aspect ratio 3. *II—Lateral and directional characteristics. H. F. Savage and B. E. Tinling. N.A.C.A. T.N.* 4042. *August* 1957.

The effects of vertical-tail size and length on the lateral and directional stability characteristics of both mid- and high-wing aeroplane arrangements were evaluated. Also evaluated were the directional control effectiveness of a rudder, and the lateral control effectiveness of ailerons and of differential deflection of the horizontal tail surfaces. The tests were conducted at a Reynolds number of 2·5 million at Mach numbers from 0·25 to 0·95.—(1.8.1.2).

Review and investigation of unsatisfactory control characteristics involving instability of pilot-airplane combination and methods for predicting these difficulties from ground tests. W. H. Phillips et al. N.A.C.A. T.N. 4064. *August* 1957.

A number of examples are presented of control difficulties which appear to result from a tendency for dynamic instability of the combination of the pilot, control system, and aeroplane. These difficulties have occurred in both conventional and power control systems. Tests of a bomber

NOTE.—*The figures in parenthesis at the end of each Summary are for office use only.*

and a fighter aeroplane equipped with hydraulic power controls have been made to study this problem. The effect of friction in the control valves of the power control systems is discussed. An analytical study of the problem and a method of detecting such control difficulties by means of ground simulator tests are presented.—(1.8.2.1).

Flight-test investigation on the Langley control-line facility of a model of a propeller-driven tail-sitter-type vertical-take-off airplane with delta wing during rapid transitions. R. O. Schade. N.A.C.A. T.N. 4070. *August* 1957.

A flight test investigation has been made on the Langley control-line facility to determine the longitudinal stability and control characteristics of a model of a propeller-driven tail-sitter-type vertical-take-off aeroplane with delta wing during rapid transitions from hovering flight to forward flight and back to hovering.—(1.8.2 × 1.12.2).

THERMO-AERODYNAMICS

Evaporative cooling at high speeds. G. Jarre. R.A.E. Lib. Trans. 678. *July* 1957.

In the first part of this paper the classical Reynolds analogy is extended to the case of a mixture of gas and vapour flowing across a wetted surface at high speed, the surface being wetted with the liquid phase of the vapour, and therefore being a seat of condensation and evaporation. In the second part of the paper numerical examples of evaporative cooling of surfaces subjected to aerodynamic heating (sweat cooling) are dealt with; some concepts of conventional hygrometry are extended to high speed. As a particular case, the effect of transverse injection of a gas having a high specific heat into the flow is analysed.—(1.9.1 × 1.1).

WINGS AND AEROFOILS—*see also* COMPRESSIBLE FLOW AND STABILITY AND CONTROL

Aerodynamic characteristics of a 40° *swept back wing of aspect ratio* 4·5. *P. S. Barna. CoA Note No.* 65. *May* 1957.

The results of the experimental investigation into the pressure distribution over a swept back wing, having an aspect ratio of 4·5 and sweep back angle of 40° at quarter chord are presented. A half model technique has been used. The wing section was R.A.E. 101 (symmetrical) with 6 per cent maximum thickness and zero camber. Measurements of chordwise pressure distributions at a number of spanwise sections were made in the incidence range 2 - 32°. The experiments were performed at Reynolds numbers of $0{\cdot}9 \times 10^6$ and 2×10^6 (based on geometric mean chord). From these measurements, lift, drag and pitching moment characteristics of the wing were calculated. Results of the experiments for small incidences have been compared with the calculated loadings obtained by methods proposed by Kuchemann.—(1.10.2.2).

Ground effects on the longitudinal characteristics of two models with wings having low aspect ratio and pointed tips. D. A. Buell and B. E. Tinling. N.A.C.A. T.N. 4044. *July* 1957.

Wind tunnel tests were conducted to determine the ground effects on a tail-less model with a wing of aspect ratio 2 and infinite taper, and on a tailed model with a triangular wing of aspect ratio 3, with flaps. Control-surface hinge moments were measured on the tail-less model. The results are compared with the predictions of the theory of Tani, *et al.*—(1.10.2.2 × 1.3.4 × 1.8.2).

HELICOPTER AERODYNAMICS

Independence of helicopter rotor derivatives under non-uniformity of induced velocity distribution at low forward speed. W. W. Bryce. CoA Report No. 110. *November* 1956.

Values of the force coefficients C_H and C_{YS}, the flapping coefficients a_0, a_1 and b_1, and the rotor derivatives x_q, z_q, y_p, x_w, z_w, $z_{\dot{w}}$, and y_v have been calculated for a typical case for the low forward speed region ($\mu = 0 - 0{\cdot}14$) for both uniform and non-uniform induced velocity and the results compared. Additional values of the flapping coefficients have been calculated for the speed range $\mu = 0{\cdot}14 - 0{\cdot}24$ and the results compared with flight measurements and with values based on the Mangler induced velocity distribution.—(1.11.3).

TESTING AND INSTRUMENTS—*see also* COMPRESSIBLE FLOW LOADS STABILITY AND CONTROL FLIGHT TESTING

*Instability in a slotted wall tunnel. J. L. King et al. C.P.*343. 1957.

Large pressure fluctuations have been observed in the working section of A.R.L.'s new 30 in. water tunnel. The present report describes investigations carried out in a 7 in. wind tunnel to examine such fluctuations in detail and also theoretical investigations which explain and describe the phenomena.—(1.12.1.1).

*The use of an araldite coated iron casting as a liner for a supersonic wind tunnel. C. S. Brown and K. G. Winter. C.P.*346. 1957.

The use of cast iron and araldite appears to overcome the disadvantages of wooden liners. The surface finishing is no more difficult than with wood and the overall manufacturing time is comparable.—(1.12.1.3 × 21).

*Multitraverse recording dilatometer. T. J. Struys and H. A. H. Griffiths. A.R.L. Note I.*61. *February* 1957.

A recorder is described in which scale expansion is obtained by making several traverses of the chart correspond to full range of the input variable. By making ten traverses of the recording chart an effective scale length of some 90 in. is obtained for a movement of the input displacement pick-up of 0·250 in.—(1.12.6).

Contribution de la recherche aéronautique au progrès de l'aviation. M. Roy. O.N.E.R.A. Pub. No. 90. *April* 1957.—(1.12).

Short notes on model-making and force measuring techniques. E. Dobbinga and G. Prast. AGARD Report 18. *February* 1956.

Seven short notes on techniques used in the Netherlands are contained. Three, on special methods of model making, are concerned respectively with propeller blades, the concave walls of curved slots and wing-fuselage fairings. Two other notes describe model-making machines and the remaining two deal with results of tests with pressure bearings in a sting holder and with an apparatus for calibrating a strain-gauge balance.—(1.12).

Les installations d'essais mises en oeuvre pour l'Atar Volant. G. Eggers et J. Jardinier. AGARD Report 59. *August* 1956.—(1.12.2 × 27.1).

A supersonic wind tunnel for Mach numbers up to 3·5. *L. E. Leavy. AGARD Report* 70. *August* 1956.

A description is given of the requirements, design, and construction of the new AVRO 27 in. × 36 in. intermittent "blow down" supersonic wind tunnel. The relative advantages and disadvantages of the "blow down" and "suck down" tunnels are compared. An outline of the factors governing the size of a tunnel designed to work at $M = 3{\cdot}5$ is given and reasons for the choice of low pressure storage.—(1.12.3).

Air supply for blow-down wind tunnels. E. J. Stollenwerk. AGARD Report 88. *August* 1956.

An air supply system for a blow-down wind tunnel is described with particular emphasis on the problem of air storage and pressure control, flow equalisation downstream of the control valve, and temperature control. The basis of the description is operational experience during the past three years on Tunnel E-1, a 12 in. × 12 in. supersonic wind tunnel of the Gas Dynamics Facility, Arnold Engineering Development Center, Tullahoma, Tennessee, U.S.A.—(1.12.1.3).

*Caragraphe. Instrument pour la détermination graphique d'écoulements plans supersoniques par la méthode des caractéristiques. G. Gontier. Pubs. Sc. et Tech. N.T.*67. 1957.

Le caragraphe est un instrument qui se compose d'un gabarit et d'un parallélogramme articulé. Il permet d'effectuer très simplement et rapidement la détermination graphique d'un écoulement supersonique, plan et irrotationnel, par la méthode des caractéristiques. L'appareil est utilisable pour les domaines où le nombre de Mach est compris entre 1 et 7; la célérité critique du son est représentée par une longueur

de 100 mm. De plus, pour les domaines où le nombre de Mach est compris entre 1 et 1·26, on a sur le gabarit des éléments qui permettent le tracé avec une précision plus grande, la célérité critique du son etant représentée par 400 mm. Des échelles, graduées en nombre de Mach et en vitesse réduite, rapport de la vitesse à la célérité critique du son, sont gravées sur le gabarit même.—(1.12 × 1.2.3).

AEROELASTICITY

On stability criteria for fluttering systems. J. D. C. Crisp. A.R.L. Report SM 250. *April* 1957.

The characteristic equation for non-trivial solutions of the equations of motion of an *n*-degree-of-freedom fluttering system reduces to a complex polynomial equation with constant coefficients which are defined by the physical parameters of the system. Here the application of the Cauchy "residue theorem" to the study of the roots of this equation and so to the stability of the system is generalised and formalised for the specifically fluttering system. A simplified, concise statement of the resulting graphical criterion is suggested and thought to have useful application for 2nd, 3rd, and 4th-order systems in flutter design and system parametric studies.—(2).

A correlation of results of a flight investigation with results of an analytical study of effects of wing flexibility on wing strains due to gusts. C. C. Shufflebarger et al. N.A.C.A. T.N. 4071. *August* 1957.

An analytical study of the effects of wing flexibility on wing strains due to gusts has been made for four spanwise stations of a four-engine bomber aeroplane, and the results have been correlated with results of a previous flight investigation.—(2 × 33.1.1).

Effects of airplane flexibility on wing strains in rough air at 5000 *feet as determined by flight tests of a large swept-wing airplane. R. H. Rhyne and H. N. Murrow. N.A.C.A. T.N.* 4107. *September* 1957.

The results of a flight investigation on a large swept-wing bomber aeroplane to determine the overall magnitude of the aeroelastic effects on the bending and shear strains in rough air show that the amplification of strain per unit acceleration in gusts, as compared with strain per unit acceleration for a "rigid" and "quasi-rigid" reference, increases with outboard spanwise station to a maximum amplification factor of 2·72.—(2 × 31.1.1).

AIRCRAFT

A report on the Arado AR 232 *transport aircraft. W. Van Nes. AGARD Report* 78. *August* 1956.

An account is given of the Arado AR 232 transport aircraft. The special ailerons and the unusual cross-country undercarriage are described and detailed performance figures are given. A description is given of the Göttinger test aeroplane fitted with suction over the inner wings and blowing over the outer wings and ailerons. The application of this system to the Arado AR 232 is also described and the possibility of using hydrogen preoxide driven pumps to provide the mass-flow is discussed. Finally, a comparison of the suction, suction-blowing and direct thrust methods of decreasing the take-off run is made.—(3 × 13).

AVIATION MEDICINE

See also INSTRUMENTS AND EQUIPMENT

*A note on the intermittency of a human operator in a control system. J. R. Ward. A.R.L. Note HE.*2. *June* 1957.—(9).

FLIGHT TESTING

See also AIRCRAFT AND PROPELLERS

Notes on the ground-run of jet-propelled aircraft during landing and take-off. G. S. Alias. AGARD Report 82. *August* 1956.

Equations for ground-run distances on an inclined runway which take account of the use of rockets during take-off and reverse thrust and braking parachutes during landing are derived in an appendix.—(13).

The function of magnetic tape in flight test data recording and processing systems. A. T. Snyder. AGARD Report 83. *August* 1956

The advantages of magnetic tape for recording flight test data are discussed in detail. A brief description of several systems which are in common use is given, and one of the Boeing Data Recording and Processing systems is fully described.—(13).

Flight techniques for determining airplane drag at high Mach numbers. De. E. Beeler et al. AGARD Report 84. *August* 1956.

Techniques investigated and developed by the N.A.C.A. High-Speed Flight Station for measuring the drag of high-speed research and fighter aeroplanes, for comparison with wind tunnel data are discussed.—(13.3).

Some unique aspects of flight test instrumentation for vertical take-off aircraft. E. R. Hinz and R. A. Fuhrman. AGARD Report 85. *August* 1956.

Aspects of flight test instrumentation which are unique to VTO aircraft are described. These aspects are discussed under three headings: hovering flight; transitional flight; and conventional flight. The idea of establishing a common space-axes system applicable to all flight regimes is discussed also, and a suggestion put forward for the establishment of a new stable platform attitude reference.—(13 × 1.12).

FUELS AND LUBRICANTS

See THERMODYNAMICS

INSTRUMENTS AND EQUIPMENT

The flight simulator in aircraft control and design. W. J. G. Pinsker. AGARD Report 71. *August* 1956.

The possibilities of simulating manually controlled flight are discussed and the principal types of flight simulators are described. Particular attention is given to the importance of realistic visual and physical flight impressions.—(18 × 9).

MATERIALS

See also AERODYNAMICS—TESTING AND INSTRUMENTS

Méthode rapide de préparation des surfaces pour les examens métallographiques. Polissage électrolytique local. P. A. Jacquet. O.N.E.R.A. Note Techniques No. 40. 1957.

A method for the local electrolytic polishing of metal specimens is described.—(21.6).

Study of the micro-nonuniformity of the plastic deformation of steel. B. B. Chechulin. N.A.C.A. T.M. 1411. *August* 1957

A new statistical method for the study of non-uniform strains is presented. By means of frequency diagrams of the axial inequality of the grains of a polycrystalline metal before and after loading, the average deviation of the strain from the mean can be determined. It is shown that steel with an austentic structure undergoes strains which differ much less from the mean than steels with ferritic or pearlitic structure. In the latter case, the deviations from the mean increase continuously with the mean strain.—(21.2.1).

Strength and ductility of bainitic steels. D. H. Desy et al. N.A.C.A. T.N. 3989. *August* 1957.

Some of the factors believed to affect the strength and ductile-to-brittle transition temperature of bainitic steels, including mean ferrite path and degree of internal strain, have been studied.—(21.2.1).

Some observations on stress-corrosion cracking of single crystals of AZ61X magnesium alloy. F. Meller and M. Metzger. N.A.C.A. T.N. 4019. *July* 1957.

Exploratory tests were made of the stress-corrosion cracking of single crystals of solution-treated AZ61X magnesium alloy in distilled water, in 0·5 and 1 per cent hydrofluoric acid, and in a salt-chromate solution. The path chosen by the crack is attributed to mechanical rather than electrochemical factors and the possible importance of prior deformation is pointed out.—(21.1).

Reduction of oxidized Nichrome V powders and sintering of Nichrome V bodies. P. Sikora and P. Clarkin. *N.A.C.A. T.N.* 4032. *September* 1957.

Methods of obtaining essentially oxide-free powders were evaluated by oxygen analyses, tensile tests, and microstructures of specimens made from reduced powders. Microstructures and tensile properties of several specimens made from reduced powder by pressing, sintering, and hot-swaging were nearly equivalent to those of wrought material. No consistent correlation existed between tensile properties and residual-oxygen content.—(21.2).

Tensile properties of Inconel X sheet under rapid-heating and constant-temperature conditions. I. M. Kurg. *N.A.C.A. T.N.* 4065. *August* 1957.

Results of rapid-heating tests of Inconel X sheet are presented for nominal temperature rates of 0·2°F to 100°F per second under constant tensile load conditions. Yield and rupture stresses are compared with the results of conventional tensile stress-strain tests at elevated temperatures. A temperature-rate parameter was used to construct master curves from which stresses and temperatures for yield and rupture can be predicted under rapid-heating conditions.—(21.2.2).

Compressive stress-strain properties of 17-7 *PH and AM* 350 *stainless-steel sheet at elevated temperatures.* B. A. Stein. *N.A.C.A. T.N.* 4074. *August* 1957.

Results of compressive stress-strain tests on 17-7 PH and AM 350 stainless steel sheet in the heat-treated and in the annealed conditions are presented for temperatures up to 1,200°F. The 17-7 PH stainless steel was heat-treated to condition TH 1,050; the AM 350, to the double-aged condition. Representative compressive stress-strain curves are given for each material at the test temperatures. From these curves significant data such as 0·2 per cent offset yield stress, Young's modulus, and secant and tangent moduli are presented.—(21.2.1).

Tensile stress-strain properties of 17-7 *PH and AM* 350 *stainless-steel sheet at elevated temperatures.* I. M. Kurg. *N.A.C.A. T.N.* 4075. *September* 1957.

Tensile stress-strain test results for 17-7 PH and AM 350 stainless steel sheet are presented for temperatures from room temperature to 1,300°F. Stress-strain curves and data for yield and ultimate stresses, Young's modulus, and elongation are given in tabular and graphical form. A comparison is made between the tensile and compressive properties.—(21.2.1).

The mechanism of thermal-gradient mass transfer in the sodium hydroxide-nickel system. C. E. May. *N.A.C.A. T.N.* 4089. *September* 1957.

"Thermal-gradient mass transfer" was investigated in the molten sodium hydroxide-nickel system. Kinetic equations are theoretically derived. Possible mechanisms (physical, electrochemical, and chemical) are discussed. Beneficial and detrimental effects of additives are interpreted in terms of the probable mechanism.—(21.3 × 21.2.2).

POWER PLANTS

See also AERODYNAMICS—TESTING AND INSTRUMENTS

The influence of design pressure ratio and divergence angle on the thrust of convergent-divergent propelling nozzles. P. F. Ashwood and D. G. Higgins. *C.P.*325. 1957.

Tests have been made to determine the thrusts obtainable from two groups of Laval-type convergent-divergent propelling nozzles over a range of pressure ratios up to 9 : 1 using air at sensibly ambient temperature. The nozzles of the first group were designed for pressure ratios of 4, 6, 8, 10 and 12 and had an included divergence angle of 20° while those of the second group were all designed for a pressure ratio of 8 and had included divergence angles of 5°, 10°, 20°, 30° and 50°.—(27 × 1.5).

Screen-type noise reduction devices for ground running of turbojet engines. W. D. Coles and W. J. North. *N.A.C.A. T.N.* 4033. *July* 1957.—(27.1 × 32.2.3).

PROPELLERS

Effects of blade plan form on free-space oscillating pressures near propellers at flight Mach numbers to 0·72. M. C. Kurbjun. *N.A.C.A. T.N.* 4068. *August* 1957.

Comparisons are made of the free-space oscillatory pressures near the tips of propellers with rectangular and tapered blade plan forms. Measurements were made at a single radial station and at three axial positions (ahead of, in the plane of, and behind the propeller disc). The effects of propellers blade plan form are shown as comparisons of the noise emitted from the rectangular- and tapered-blade propellers with changes in operating parameters of Mach number, power, and engine speed.—(29 × 13).

FATIGUE

See also AEROELASTICITY

The fatigue strength of aluminium alloy lugs J. Schijve and F. A. Jacobs. *NLL-TN M.*2024. *January* 1957.

Fatigue diagrams have been established for un-notched specimens and two types of lugs of 2024-T aluminium alloy. A survey of available data is given. Different factors which may effect the fatigue behaviour of lugs are discussed. Attention is drawn to fretting in lugs. Some remarks are made with respect to designing lugs for fatigue.—(31.2.3.2 × 33.2.4.13.1).

Scatter of fatigue life and fatigue strength in aircraft structural materials and parts. W. Weibull. *FFA Report* 73. 1957.

The fatigue properties of a specimen or of a structural part subjected to some well-defined type of loading may be described by one single S-N curve, preferably the median one, and the probable deviations from this curve. This scatter may be taken either in the horizontal or in the vertical direction. With respect to fatigue design the scatter of strength offers advantages over the scatter of life which make its determination worthwhile. These considerations are illustrated by means of data from fatigue tests.—(31.2 × 31.3).

Effect of crystal orientation on fatigue-crack initiation in polycrystalline aluminum alloys. J. G. Weinberg and J. A. Bennett. *N.A.C.A. T.N.* 3990. *August* 1957.

Tests on large-grained specimens of 1100 and 5052 aluminium alloys indicate that fatigue cracks initiate in pre-existing slipbands on planes that are parallel to (111) planes. Bending and torsional fatigue tests were conducted to determine which factors influence the initiation of cracks. In bending fatigue it appears that grain size and shape as well as resolved shear stress were influential, while in torsional fatigue the resolved shear stress appeared to be the only important factor.—(31.2.2.3).

SCIENCE—GENERAL

See also POWER PLANTS

The modifications of lead oxide in accumulators. H. Bode and E. Voss. *R.A.E. Lib. Trans.* 659. *June* 1957.

In addition to the well known tetragonal modification of lead oxide an orthorhombic form is found at the positive electrode of a charged accumulator. It can be shown that there is a strict spatial relationship between the crystal structure of this modification and that of the red monoxide of lead as well as with that of metallic lead itself.—(32).

Processes in the fusion and vaporization of wires with very high current densities. J. Wrana. *R.A.E. Lib. Trans.* 671. *June* 1957.

Several papers appeared prior to 1939 on the response of wires to heavy surge currents. In this report the fusion and vaporisation of copper and other wires has been studied with an oscilloscope (current and potential curves), and by photographing the wire, at current densities between 200,000 and 1 million amps/sq. mm. Two possible types of second discharge (after disintegration of the wire in the main discharge) have been investigated.—(32.2.1).

Contribution a la mesure des chaleurs spécifiques des gaz et des vapeurs. M. Huetz-Aubert. *Pubs. Sc. et Tech. N.T.*68. 1957.—(32.2.2 × 34)

STRUCTURES

LOADS—*see also* AEROELASTICITY

Impact-loads investigation of a chine-immersed model having a circular-arc transverse shape. P. M. Edge. N.A.C.A. T.N. 4103. *September* 1957.

Hydrodynamic-impact-loads data were obtained from tests of a narrow-beam model having a circular-arc transverse shape. Tests were run in smooth water at fixed trims over a range of landing conditions for a range of beam-loading coefficients. The data are compared with loads predicted by theory and with experimental loads obtained from similar tests with a concave-convex transversely curved shape.—(33.1.2).

Impact-loads investigation of chine-immersed model having a longitudinally curved bow and a V-bottom with a dead-rise angle of 30°. P. M. Edge and J. S. Mixson. N.A.C.A. T.N. 4106. *September* 1957.

Hydrodynamic-impact-loads data were obtained with a chine-immersed model having a dead-rise angle of 30° and the forward half longitudinally curved upward. Impacts were made at fixed trim in smooth water over a range of landing-approach conditions. The data are evaluated as to the extent of bow immersion, and the maximum loads obtained are compared with loads predicted by theory for a straight-keel model.—(33.1.2).

THEORY AND ANALYSIS—*see also* FATIGUE

Flexural vibrations, taking account of the beam mass and the external and internal damping. H. Holzer. R.A.E. Lib. Trans. 673. *June* 1957.

The evaluation of the flexural vibrations of a vibrating reed, electromagnetically excited at its free end is discussed. Account is taken of external and internal friction or damping —the latter by assuming a linear law in which the damping force is proportional to

$$\frac{\partial}{\partial t}\left[\frac{\partial^2 \eta}{\partial n^2}\right]$$

where η is the transverse displacement at any point along the reed.—(33.2.4.1.10).

Flexural vibrations, account being taken of the mass of the beam as well as of internal and external damping. K. Muto. R.A.E. Lib. Trans. 674. *June* 1957.

The same ground as Library Translation No. 673 is covered. However, its author disputes certain of the assumptions of the earlier author. In particular he takes account of internal damping in shear as well as in bending, which, according to him, the earlier writer overlooks. He arrives at different conclusions in consequence. The present paper is primarily concerned with the vibrational response of structures to earthquakes.—(33.2.4.1.10).

The effect of end-thrust on the flexural vibration of a beam with internal damping. K. Sezawa. R.A.E. Lib. Trans. 676. *July* 1957.

The effect of end-thrust on the fundamental flexural vibration frequency and the corresponding effective damping factor is examined. Boundary conditions considered are: both ends supported, both ends encastre, and one end supported with the other encastre. It is found that the effective damping factor is not greatly changed by the end-thrust, but that the vibration period is profoundly altered by the end-thrust per unit cross-section. Anything from an aperiodic response to critical stability can be obtained by varying this factor.—(33.2.4.1.10).

Approximate analysis of effects of large deflections and initial twist on torsional stiffness of a cantilever plate subjected to thermal stresses. R. R. Heldenfels and L. F. Vosteen. N.A.C.A. T.N. 4067. *August* 1957.

An approximate analysis of the nonlinear effects of initial twist and large deflections on the torsional stiffness of a cantilever plate subjected to a non-uniform temperature distribution is presented. The von Kármán large-deflection equations are satisfied through the use of a variational principle. Results calculated by this analysis are in satisfactory agreement with measured torsional deformations and changes in natural frequency.—(33.2.4.5.9).

Calculated and measured stresses in simple panels subject to intense random acoustic loading including the near noise field of a turbojet engine. L. W. Lassiter and R. W. Hess. N.A.C.A. T.N. 4076. *September* 1957.

Flat aluminium panels were tested in the near noise fields of an air jet and turbo-jet engine. The resulting stresses in the panels are compared with those calculated by generalised harmonic analysis. To make the stress calculations, supplementary data relating to the transfer characteristics, damping, and static response of flat and curved panels under periodic loading are necessary and were determined experimentally. Detailed data on the near pressure field of the turbo-jet engine is included.—(33.2.4.5.10).

Practical solution of plastic deformation problems in elastic-plastic range. A. Mendelson and S. S. Manson. N.A.C.A. T.N. 4088. *September* 1957.

A practical method for solving plastic deformation problems in the elastic-plastic range is presented. The method is one of successive approximations and is illustrated by four examples which include a flat plate with temperature distribution across the width, a thin shell with axial temperature distribution, a solid cylinder with radial temperature distribution, and a rotating disc with radial temperature distribution.—(33.2.4.0.9).

TESTING

On the excitation of pure natural modes in aircraft resonance testing. R. W. Traill-Nash. A.R.L. Report SM 254. *July* 1957.

A method is proposed for systematic adjustment of force levels to produce a pure undamped natural mode of vibration in multi-point excitation of aircraft structures. The question of optimum numbers of measuring stations and exciters is examined and some conclusions are reached.—(33.3.2).

THERMODYNAMICS

See also SCIENCE—GENERAL

Speed of evaporation and drag coefficients for a droplet in a gas stream. A. Muggia. R.A.E. Lib. Trans. 679. *July* 1957.

The field of a gas stream around a spherical evaporating drop at low Mach and Reynolds numbers has been investigated when the temperature of the drop is time-invariant. By extending Oseen's theory on the field around a spherical solid to the case of an evaporating sphere, the variations of velocity, pressure, temperature, enthalpy and concentration of the vapour in the field are determined. In addition, the speed of evaporation and the forces exerted by the stream on the drop are calculated.—(34.4).

Mesure instantanée des températures de flammes. A. Moutet. O.N.E.R.A. Pub. No. 88. 1957.

A summary is given of optical methods of flame temperature measurement and special note is made of recent developments. Reference is made to the problem of short time response in connection with the study of combustion instabilities.—(34.2).

Recherches sur quelques propriétés de certains hypergols. J. Françon. Pubs. Sc. et Tech. N.T. 66. 1957.

The results of some research on the properties of liquid mixtures which spontaneously ignite on contact are given.—(34.1.1).

Spark ignition of flowing gases. C. C. Swett. N.A.C.A. Report 1287. 1956.

Research conducted at the N.A.C.A. Lewis laboratory on ignition of flowing gases by means of long-duration discharges is summarised and analysed. Data showing the effect of a flowing combustible mixture on the physical and electrical characteristics of spark discharges and data showing the effects of variables on the spark energy required for ignition of the combustible mixture are presented. A theory of ignition is described.—(34.1.2).

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